

**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

|  |           |   |
|--|-----------|---|
| <b>(51) International Patent Classification <sup>6</sup> :</b><br><b>A61K 31/52 // (A61K 31/52, 31:40)</b>   | <b>A1</b> | <b>(11) International Publication Number:</b> <b>WO 99/34804</b><br><b>(43) International Publication Date:</b> 15 July 1999 (15.07.99)   |
| <b>(21) International Application Number:</b> PCT/US99/00366<br><b>(22) International Filing Date:</b> 7 January 1999 (07.01.99)<br><br><b>(30) Priority Data:</b><br>09/003,930                      8 January 1998 (08.01.98)                      US<br><br><b>(71) Applicant:</b> THE UNIVERSITY OF VIRGINIA PATENT FOUNDATION [US/US]; Suite 1-110, 1224 West Main Street, Charlottesville, VA 22903 (US).<br><br><b>(72) Inventors:</b> LINDEN, Joel, M.; 2715 Caribbean Lane, Charlottesville, VA 22902 (US). SULLIVAN, Gail, W.; 568 Taylor's Gap Road, Charlottesville, VA 22903 (US). SAREMBOCK, Ian; Health Sciences Center, Box 158, Charlottesville, VA 22903 (US). SHELD, W., Michael; 2075 Earlysville Road, Earlysville, VA 22936 (US).<br><br><b>(74) Agent:</b> VIKSNINS, Ann, S.; Schwegman, Lundberg, Woessner & Kluth, P.O. Box 2938, Minneapolis, MN 55402 (US). |           | <b>(81) Designated States:</b> AU, CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).<br><br><b>Published</b><br><i>With international search report.<br/>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> |
| <b>(54) Title:</b> A <sub>2A</sub> ADENOSINE RECEPTOR AGONISTS<br><br><b>(57) Abstract</b><br><br>Agonists of A <sub>2A</sub> adenosine receptors in combination with rolipram, its derivatives or other Type IV phosphodiesterase (PDE) inhibitors are effective for the treatment of inflammatory diseases.  |           |   |

***FOR THE PURPOSES OF INFORMATION ONLY***

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

|           |                          |           |  |           |  |           |                          |
|-----------|--------------------------|-----------|--|-----------|--|-----------|--------------------------|
| <b>AL</b> | Albania                  | <b>ES</b> | Spain                                    | <b>LS</b> | Lesotho                                      | <b>SI</b> | Slovenia                 |
| <b>AM</b> | Armenia                  | <b>FI</b> | Finland                                  | <b>LT</b> | Lithuania                                    | <b>SK</b> | Slovakia                 |
| <b>AT</b> | Austria                  | <b>FR</b> | France                                   | <b>LU</b> | Luxembourg                                   | <b>SN</b> | Senegal                  |
| <b>AU</b> | Australia                | <b>GA</b> | Gabon                                    | <b>LV</b> | Latvia                                       | <b>SZ</b> | Swaziland                |
| <b>AZ</b> | Azerbaijan               | <b>GB</b> | United Kingdom                           | <b>MC</b> | Monaco                                       | <b>TD</b> | Chad                     |
| <b>BA</b> | Bosnia and Herzegovina   | <b>GE</b> | Georgia                                  | <b>MD</b> | Republic of Moldova                          | <b>TG</b> | Togo                     |
| <b>BB</b> | Barbados                 | <b>GH</b> | Ghana                                    | <b>MG</b> | Madagascar                                   | <b>TJ</b> | Tajikistan               |
| <b>BE</b> | Belgium                  | <b>GN</b> | Guinea                                   | <b>MK</b> | The former Yugoslav<br>Republic of Macedonia | <b>TM</b> | Turkmenistan             |
| <b>BF</b> | Burkina Faso             | <b>GR</b> | Greece                                   | <b>ML</b> | Mali   | <b>TR</b> | Turkey                   |
| <b>BG</b> | Bulgaria                 | <b>HU</b> | Hungary                                  | <b>MN</b> | Mongolia                                     | <b>TT</b> | Trinidad and Tobago      |
| <b>BJ</b> | Benin                    | <b>IE</b> | Ireland                                  | <b>MR</b> | Mauritania                                   | <b>UA</b> | Ukraine                  |
| <b>BR</b> | Brazil                   | <b>IL</b> | Israel                                   | <b>MW</b> | Malawi                                       | <b>UG</b> | Uganda                   |
| <b>BY</b> | Belarus                  | <b>IS</b> | Iceland                                  | <b>MX</b> | Mexico                                       | <b>US</b> | United States of America |
| <b>CA</b> | Canada                   | <b>IT</b> | Italy                                    | <b>NE</b> | Niger  | <b>UZ</b> | Uzbekistan               |
| <b>CF</b> | Central African Republic | <b>JP</b> | Japan                                    | <b>NL</b> | Netherlands                                  | <b>VN</b> | Viet Nam                 |
| <b>CG</b> | Congo                    | <b>KE</b> | Kenya                                    | <b>NO</b> | Norway                                       | <b>YU</b> | Yugoslavia               |
| <b>CH</b> | Switzerland              | <b>KG</b> | Kyrgyzstan                               | <b>NZ</b> | New Zealand                                  | <b>ZW</b> | Zimbabwe                 |
| <b>CI</b> | Côte d'Ivoire            | <b>KP</b> | Democratic People's<br>Republic of Korea | <b>PL</b> | Poland                                       |           |                          |
| <b>CM</b> | Cameroon                 | <b>KR</b> | Republic of Korea                        | <b>PT</b> | Portugal                                     |           |                          |
| <b>CN</b> | China                    | <b>KZ</b> | Kazakstan                                | <b>RO</b> | Romania                                      |           |                          |
| <b>CU</b> | Cuba                     | <b>LC</b> | Saint Lucia                              | <b>RU</b> | Russian Federation                           |           |                          |
| <b>CZ</b> | Czech Republic           | <b>LI</b> | Liechtenstein                            | <b>SD</b> | Sudan  |           |                          |
| <b>DE</b> | Germany                  | <b>LK</b> | Sri Lanka                                | <b>SE</b> | Sweden                                       |           |                          |
| <b>DK</b> | Denmark                  | <b>LR</b> | Liberia                                  | <b>SG</b> | Singapore                                    |           |                          |
| <b>EE</b> | Estonia                  |           |  |           |  |           |                          |

## A<sub>2a</sub> ADENOSINE RECEPTOR AGONISTS

### Background of the Invention

#### Field of the Invention

5           The present invention relates to methods and compositions for treating inflammatory diseases.

#### Discussion of the Background

          The release of inflammatory cytokines such as tumor necrosis factor-alpha (TNF $\alpha$ ) by leukocytes is a means by which the immune system combats  
10   pathogenic invasions, including infections. Cytokines stimulate neutrophils to enhance oxidative (e.g., superoxide and secondary products) and nonoxidative (e.g., myeloperoxidase and other enzymes) inflammatory activity. Inappropriate and over-release of cytokines can produce counterproductive exaggerated pathogenic effects through the release of tissue-damaging oxidative and  
15   nonoxidative products (Tracey, K. G. et al., J. Exp. Med., vol. 167, pp. 1211-1227 (1988); and Männel, D. N. et al., Rev. Infect. Dis., vol. 9 (suppl. 5), pp. S602-S606 (1987)).

          For example, inflammatory cytokines have been shown to be pathogenic in: arthritis (Dinarello, C. A., Semin. Immunol., vol. 4, pp. 133-45 (1992));  
20   ischemia (Seekamp, A. et al., Agents-Actions-Supp., vol. 41, pp. 137-52 (1993)); septic shock (Männel, D. N. et al., Rev. Infect. Dis., vol. 9 (suppl. 5), pp. S602-S606 (1987)); asthma (Cembrzynska Nowak M. et al., Am. Rev. Respir. Dis., vol. 147, pp. 291-5 (1993)); organ transplant rejection (Imagawa, D. K. et al., Transplantation, vol. 51, pp. 57-62 (1991)); multiple sclerosis (Hartung, H. P.,  
25   Ann. Neurol., vol. 33, pp. 591-6 (1993)); and AIDS (Matsuyama, T. et al., AIDS, vol. 5, pp. 1405-1417 (1991)). In addition, superoxide formation in leukocytes has been implicated in promoting replication of the human immunodeficiency virus (HIV) (Legrand-Poels, S. et al., AIDS Res. Hum. Retroviruses, vol. 6, pp. 1389-1397 (1990)).

30           It is well known that adenosine and some relatively nonspecific analogs of adenosine decrease neutrophil production of inflammatory oxidative products

- (Cronstein, B. N. et al., Ann. N.Y. Acad. Sci., vol. 451, pp. 291-314 (1985); Roberts, P. A. et al., Biochem. J., vol. 227, pp. 669-674 (1985); Schrier, D. J. et al., J. Immunol., vol. 137, pp. 3284-3289 (1986); Cronstein, B. N. et al., Clinical Immunol. and Immunopath., vol. 42, pp. 76-85 (1987); Iannone, M. A. et al., in Topics and Perspectives in Adenosine Research, E. Gerlach et al., eds., Springer-Verlag, Berlin, pp. 286-298 (1987); McGarrity, S. T. et al., J. Leukocyte Biol., vol. 44, pp. 411-421 (1988); De La Harpe, J. et al., J. Immunol., vol. 143, pp. 596-602 (1989); McGarrity, S. T. et al., J. Immunol., vol. 142, pp. 1986-1994 (1989); and Nielson, C. P. et al., Br. J. Pharmacol., vol. 97, pp. 882-888 (1989)).
- For example, adenosine has been shown to inhibit superoxide release from neutrophils stimulated by chemoattractants such as the synthetic mimic of bacterial peptides, f-met-leu-phe (fMLP), and the complement component C<sub>3a</sub> (Cronstein, B. N. et al., J. Immunol., vol. 135, pp. 1366-1371 (1985)). Adenosine can decrease the greatly enhanced oxidative burst of PMN (neutrophil) first primed with TNF- $\alpha$  (an inflammatory cytokine) and then stimulated by a second stimulus such as f-met-leu-phe (Sullivan, G. W. et al., Clin. Res., vol. 41, p. 172A (1993)). There is evidence that *in vivo* adenosine has anti-inflammatory activity (Firestein, G. S. et al., Clin. Res., vol. 41, p. 170A (1993); and Cronstein, B. N. et al., Clin. Res., vol. 41, p. 244A (1993)).
- Additionally, it has been reported that adenosine can decrease the rate of HIV replication in a T-cell line (Sipka, S. et al., Acta Biochim. Biophys. Hung., vol. 23, pp. 75-82 (1988)).

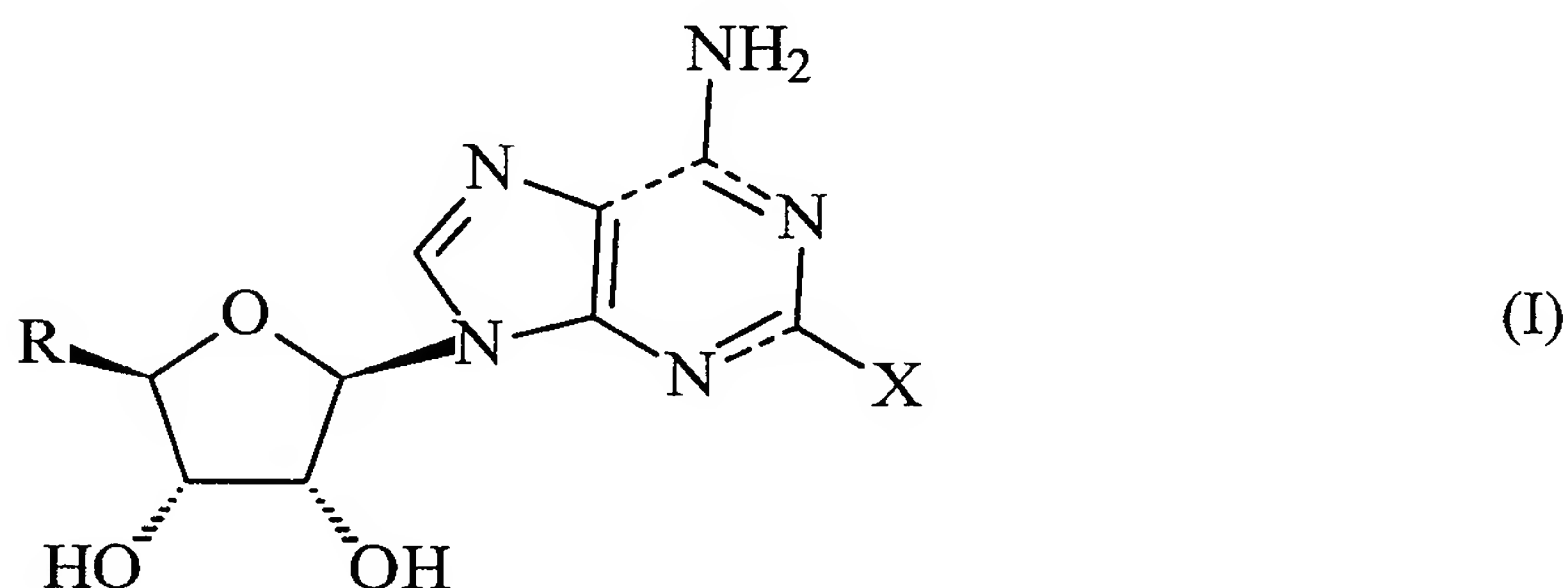
It has been suggested that there is more than one subtype of adenosine receptor on neutrophils that have opposite effects on superoxide release (Cronstein, B. N. et al., J. Clin. Invest., vol. 85, pp. 1150-1157 (1990)). The existence of A<sub>2A</sub> receptor on neutrophils was originally demonstrated by Van Calker et al. (Van Calker, D. et al., Eur. J. Pharmacology, vol. 206, pp. 285-290 (1991)).

There has been progressive development of compounds that are more and more potent and selective as agonists of A<sub>2A</sub> adenosine receptors based on radioligand binding assays and physiological responses. Initially, compounds with little or no selectivity for A<sub>2A</sub> receptors were used, such as adenosine itself or 5'-carboxamides of adenosine, such as 5'-N-ethylcarboxyamidoadenosine

(NECA) (Cronstein, B. N. et al., J. Immunol., vol. 135, pp. 1366-1371 (1985)). Later, it was shown that addition of 2-alkylamino substituents increased potency and selectivity, e.g., CV 1808 and CGS21680 (Jarvis, M. F. et al., J. Pharmacol. Exp. Ther., vol. 251, pp. 888-893 (1989)). 2-Alkoxy-substituted adenosine  
5 derivatives such as WRC-0090 are even more potent and selective as agonists on the coronary artery  $A_{2A}$  receptor (Ukena, M. et al., J. Med. Chem., vol. 34, pp. 1334-1339 (1991)). The 2-alkylhydrazino adenosine derivatives, e.g., SHA 211 (also called WRC-0474) have also been evaluated as agonists at the coronary artery  $A_{2A}$  receptor (Niiya, K. et al., J. Med. Chem., vol. 35, pp.  
10 45574561 (1992)).

There is one report of the combination of relatively nonspecific adenosine analogs, R-phenylisopropyladenosine (R-PIA) and 2-chloroadenosine (Cl-Ado) with a phosphodiesterase (PDE) inhibitor resulting in a lowering of neutrophil oxidative activity (Iannone, M. A. et al., in Topics and Perspectives in  
15 Adenosine Research, E. Gerlach et al., Eds., Springer-Verlag, Berlin, pp. 286-298 (1987)). However, R-PIA and Cl-Ado analogs are actually more potent activators of  $A_1$  adenosine receptors than of  $A_{2A}$  adenosine receptors and, thus, are likely to cause side effects due to activation of  $A_1$  receptors on cardiac muscle and other tissues causing effects such as "heart block."

20 Linden et al. SN 08/272,821 is based on the discovery that inflammatory diseases may be effectively treated by the administration of drugs which are selective agonists of  $A_{2A}$  adenosine receptors, preferably in combination with a phosphodiesterase inhibitor. An embodiment of the Linden et al. invention provides a method for treating inflammatory diseases by administering an  
25 effective amount of an  $A_{2A}$  adenosine receptor of the following formula:

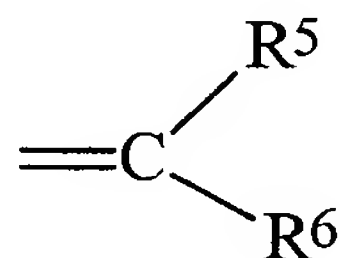


wherein X is a group selected from the group consisting of  $-OR^1$ ,  $-NR^2R^3$ , and  $-NH-N=R^4$ ;

wherein  $R^1$  is  $C_{1-4}$ -alkyl;  $C_{1-4}$ -alkyl substituted with one or more  $C_{1-4}$ -alkoxy groups, halogens (fluorine, chlorine, or bromine), hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, di( $C_{1-4}$ -alkyl)amino groups, or  $C_{6-10}$ -aryl groups (wherein the aryl groups may be substituted with one or more halogens (fluorine, chlorine, or bromine),  $C_{1-4}$ -alkyl groups, hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, or di( $C_{1-4}$ -alkyl)amino groups);  $C_{6-10}$ -aryl; or  $C_{6-10}$ -aryl substituted with one or more halogens (fluorine, chlorine, or bromine), hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, or di( $C_{1-4}$ -alkyl)amino groups, or  $C_{1-4}$ -alkyl groups;

one of  $R^2$  and  $R^3$  has the same meaning as  $R^1$  and the other is hydrogen;

$R^4$  is a group having the formula:

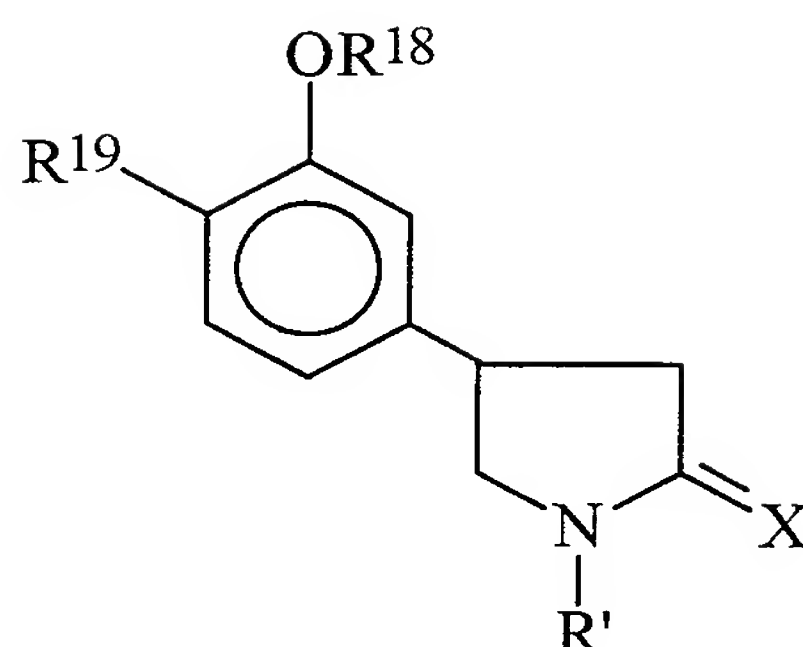


wherein each of  $R^5$  and  $R^6$  independently may be hydrogen,  $C_{3-7}$ -cycloalkyl, or any of the meanings of  $R^1$ , provided that  $R^5$  and  $R^6$  are not both hydrogen; and

R is  $-\text{CH}_2\text{OH}$ ,  $-\text{CH}_2\text{H}$ ,  $-\text{CO}_2R^7$ , or  $-\text{C}(=\text{O})\text{NR}^8\text{R}^9$ ; wherein  $R^7$  has the same meaning as  $R^1$  and wherein  $R^8$  and  $R^9$  have the same meanings as  $R^5$  and  $R^6$  and  $R^8$  and  $R^9$  may both be hydrogen.

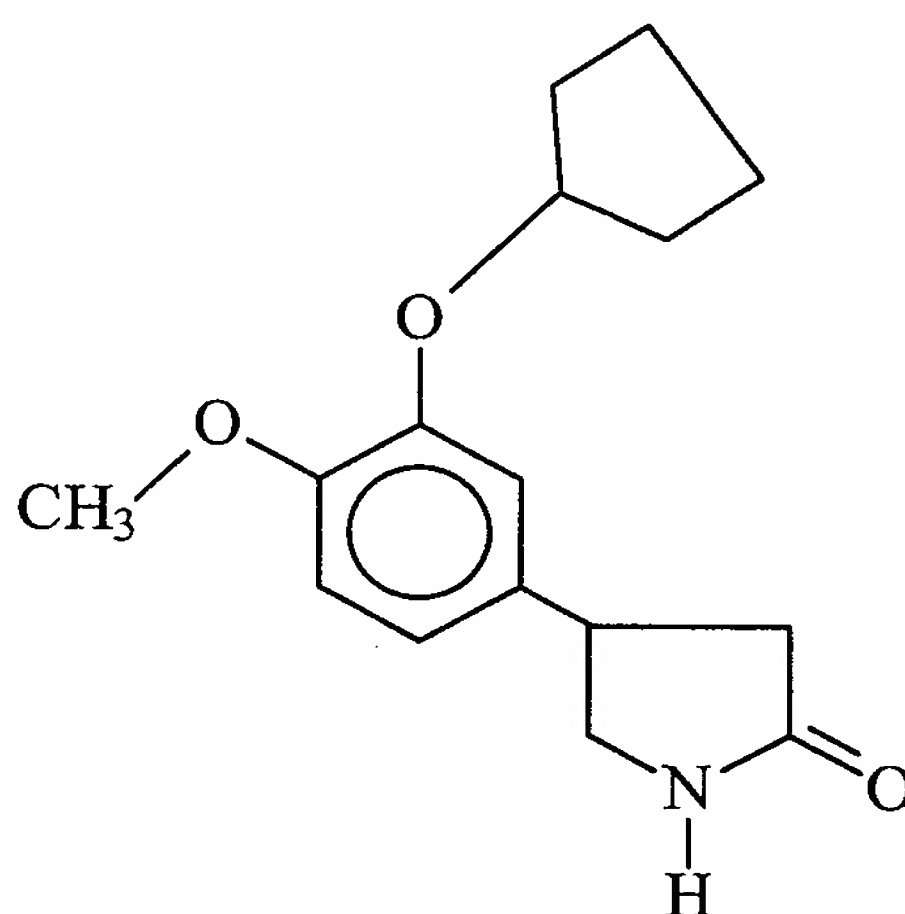
In a preferred embodiment, the Linden et al. invention involves the administration of a Type IV phosphodiesterase (PDE) inhibitor in combination with the  $A_{2A}$  adenosine receptor agonist. The Type IV phosphodiesterase (PDE) inhibitor can be racemic and optically active 4-(polyalkoxyphenyl)-2--pyrrolidones of the following formula:

5



(disclosed and described in U.S. Patent Number 4,193,926) wherein  $R^{18}$  and  $R^{19}$  each are alike or different and are hydrocarbon radicals having up to 18 carbon atoms with at least one being other than methyl, a heterocyclic ring, or alkyl of 1-5 carbon atoms which is substituted by one or more of halogen atoms, hydroxy, carboxy, alkoxy, alkoxycarbonyl or an amino group; amino;  $R'$  is a hydrogen atom, alkyl, aryl or acyl; and X is an oxygen atom or a sulfur atom.

Rolipram is an example of a suitable Type IV phosphodiesterase or PDE inhibitor included within the above formula. Rolipram has the following structure:



The present invention is based on the inventors' discovery that improved effective treatment of inflammatory disease is achieved by the administration of certain agonists of  $A_{2A}$  adenosine receptors in combination with rolipram or rolipram derivatives that are Type IV phosphodiesterase or PDE inhibitors.



### Summary of the Invention

Accordingly, one object of the present invention is to provide a novel and improved method for treating inflammatory diseases.

It is another object of the present invention to provide novel and  
5 improved compositions for the treatment of inflammatory disease.

These and other objects, which will become better understood during the course of the following detailed description, have been achieved by the inventors' discovery of improved compositions and methods for effectively treating inflammatory diseases by administration of an agonist of an  $A_{2A}$   
10 adenosine receptor in combination with rolipram or a rolipram derivative that is a Type IV phosphodiesterase (PDE) inhibitor.

### Brief Description of the Drawings

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better  
15 understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 illustrates the relative potencies of adenosine analogs to modulate  $TNF_{\alpha}$ -primed fMLP-stimulated polymorphonuclear cell (PMN) chemiluminescence as a measure of PMN production of oxidative products (0,  
20 no  $TNF_{\alpha}$ ;  $\Delta$ , WRC-0474[SHA 211] +  $TNF_{\alpha}$ ;  $\square$ , GCS 21680 +  $TNF_{\alpha}$ ; and  $\blacktriangle$ , adenosine +  $TNF_{\alpha}$ );

Figure 2 illustrates the synergistic effect of WRC-0474[SHA 211] and 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone (rolipram) in inhibiting  $TNF_{\alpha}$ -primed (10 U/ml), fMLP-stimulated (100 nM) PMN superoxide  
25 production: 0, no 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone;  $\blacktriangle$ , 3 nM 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone;  $\square$ , 30 nM 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone; and, 300 nM 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone;

Figure 3 illustrates the synergistic effect of WRC-0474[SHA 211] and  
30 rolipram in inhibiting  $TNF_{\alpha}$ -stimulated adherent PMN superoxide release;

Figure 4 illustrates the effect of WRC-0474[SHA 211] and rolipram on  $TNF_{\alpha}$ -stimulated PMN adherence to a fibrinogen-coated surface;



Figure 5 illustrates synergy between  $A_{2A}$  adenosine receptor agonists and Rolipram in inhibiting superoxide release from  $TNF\alpha$ -stimulated adherent human neutrophils;

Figure 6 illustrates the effects of WRC-0470 and rolipram on the oxidative activity of neutrophils in whole blood;

Figure 7 illustrates the effects of WRC-0470 and rolipram on the release of  $TNF\alpha$  from adherent human monocytes and that this activity is dependent on binding of the adenosine agonist to  $A_{2A}$  adenosine receptors;

Figure 8 illustrates the effect of WRC-0470 on white blood cell pleocytosis in rats;

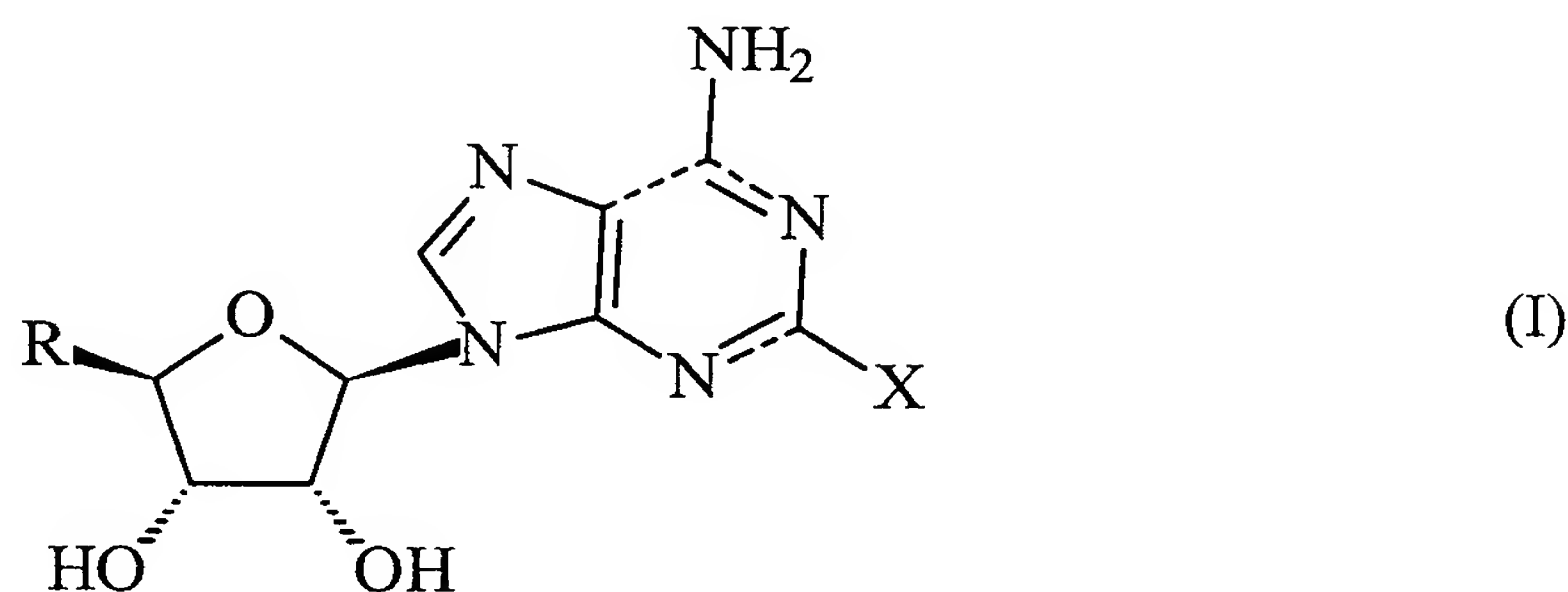
Figure 9 illustrates the effect of WRC-0470 on blood-brain-barrier permeability in rats;

Figure 10 illustrates the effect of rolipram on white blood cell pleocytosis in rats; and

Figure 11 illustrates the combined effect of WRC-0470 and rolipram on white blood cell pleocytosis in rats.

#### Detailed Description of the Preferred Embodiments

Thus, in a first embodiment, the present invention provides a method for treating inflammatory diseases by administering an effective amount of a compound of formula (I):



wherein X is a group selected from the group consisting of  $-OR^1$ ,  $-NR^2R^3$ , and  $-NH-N=R^4$ ;

wherein  $R^1$  is  $C_{1-4}$ -alkyl;  $C_{1-4}$ -alkyl substituted with one or more  $C_{1-4}$ -alkoxy groups, halogens, (fluorine, chlorine, or bromine), hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, di( $C_{1-4}$ -alkyl)amino groups, or

C<sub>6-10</sub>-aryl groups (wherein the aryl groups may be substituted with one or more halogens (fluorine, chlorine, or bromine), C<sub>1-4</sub>-alkyl groups, hydroxy groups, amino groups, mono(C<sub>1-4</sub>-alkyl)amino groups, or di(C<sub>1-4</sub>-alkyl)amino groups); C<sub>6-10</sub>-aryl; or C<sub>6-10</sub>-aryl substituted with one or more halogens (fluorine, chlorine, or bromine), hydroxy groups, amino groups, mono(C<sub>1-4</sub>-alkyl)amino groups, or di(C<sub>1-4</sub>-alkyl)amino groups, or C<sub>1-14</sub>-alkyl groups;

one of R<sup>2</sup> and R<sup>3</sup> has the same meaning as R<sup>1</sup> and the other is hydrogen;

R<sup>4</sup> is a group having the formula (II)



wherein each of R<sup>5</sup> and R<sup>6</sup> independently may be hydrogen, C<sub>3-7</sub>-cycloalkyl, or any of the meanings of R<sup>1</sup>, provided that R<sup>5</sup> and R<sup>6</sup> are not both hydrogen;

Examples of suitable C<sub>6-10</sub>-aryl groups include phenyl and naphthyl.

Preferably, the compound of formula (I) has X being a group of the formula (III)



wherein n is an integer from 1-4, preferably 2, and Ar is a phenyl group, tolyl group, naphthyl group, xylyl group, or mesityl group. Most preferably, Ar is a para-tolyl group and n = 2.

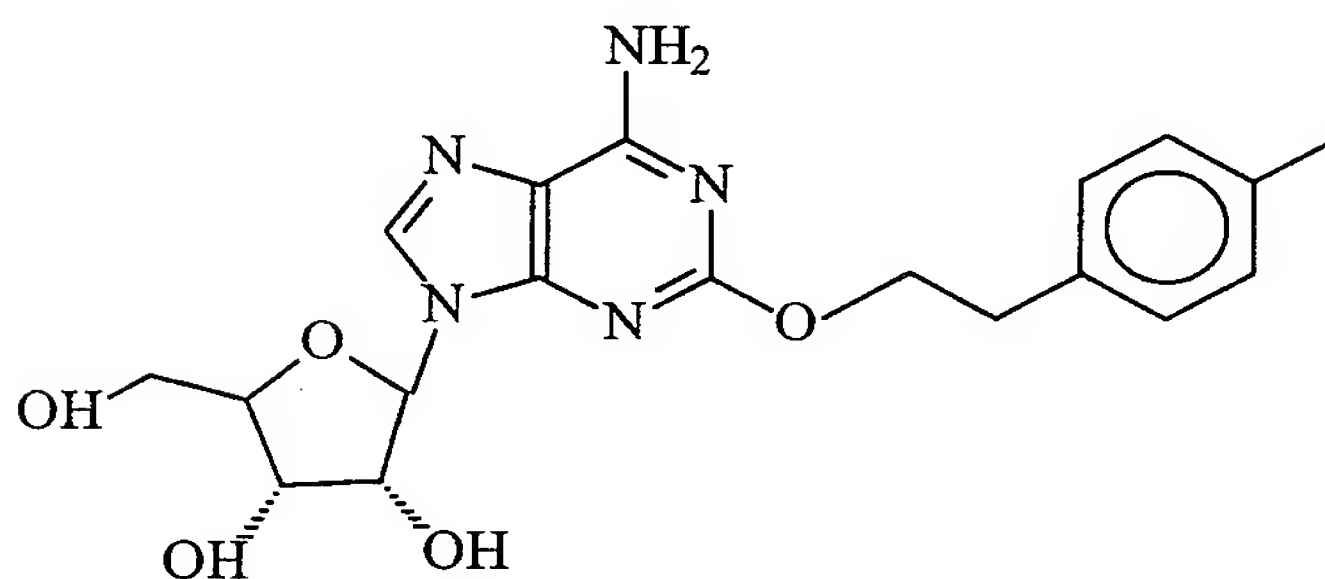
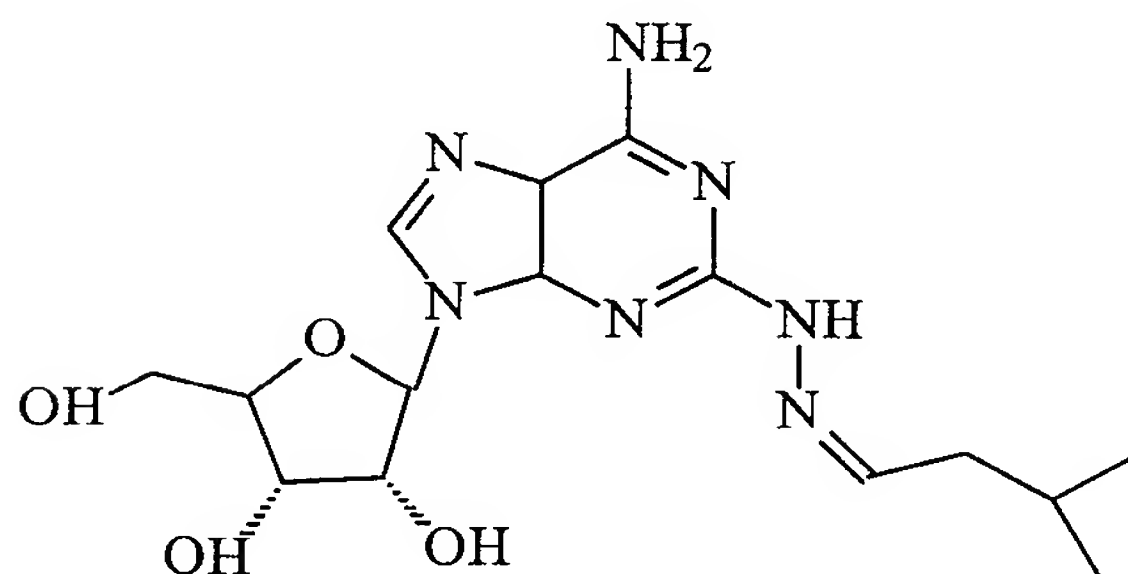
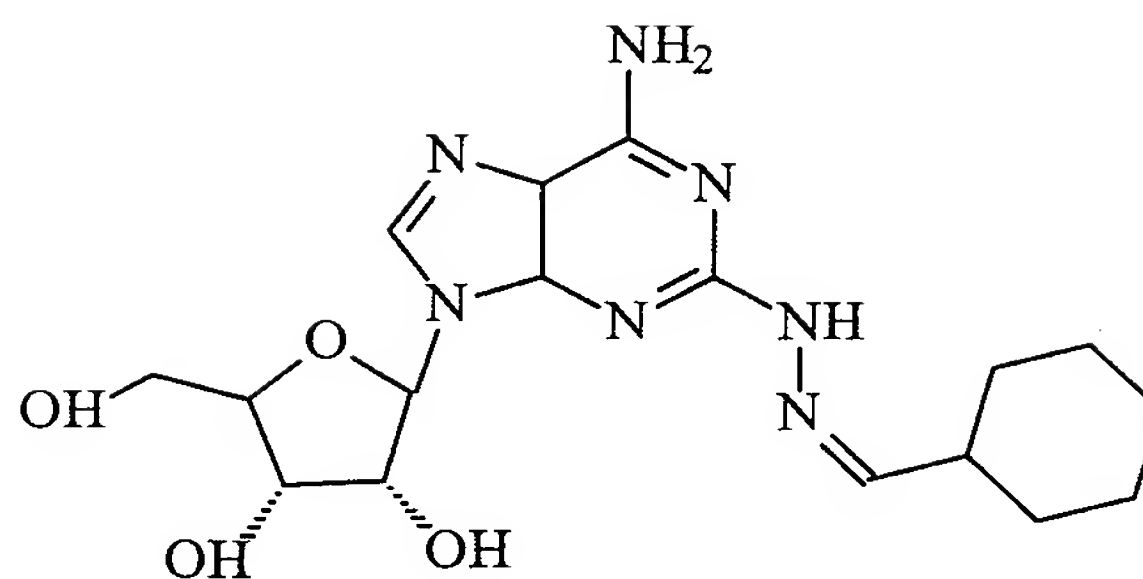
Even more preferably, the compound of formula (IV) has X being a group of the formula (I)



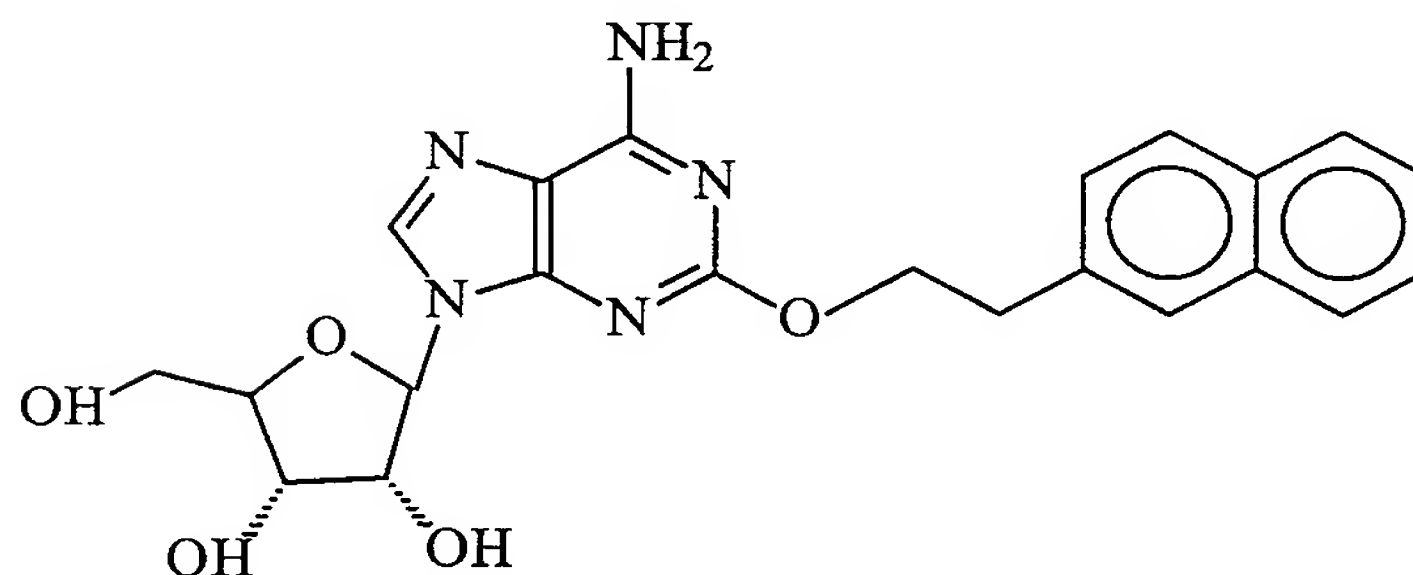
wherein Cy is a C<sub>3-7</sub>-cycloalkyl group, preferably cyclohexyl or a C<sub>1-4</sub>-alkyl group, preferably isopropyl.

Specific examples of such compounds of formula (I) include WRC-0470, WRC-0474 [SHA 211], WRC-0090 and WRC-0018, shown below:

9



and



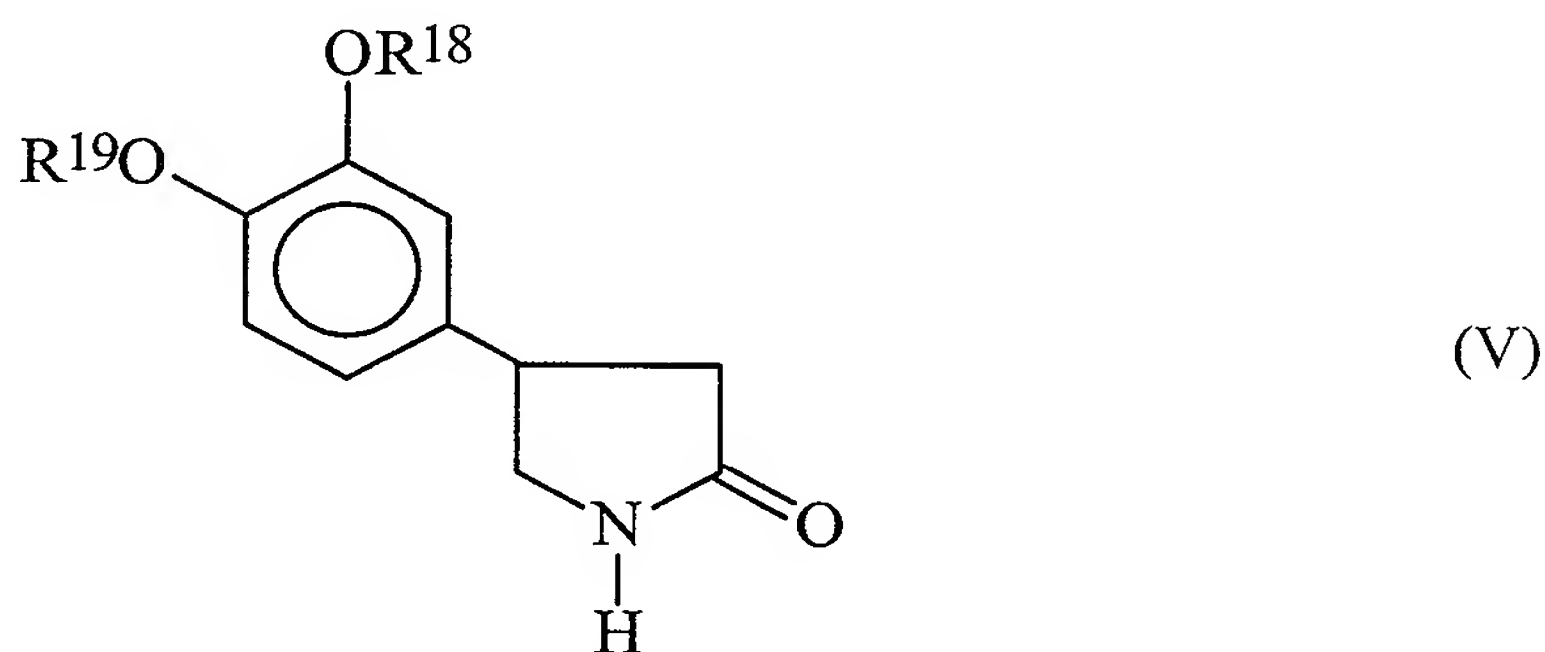
Of these specific examples, WRC-0474[SHA 211] and WRC-0470 are particularly preferred.

Such compounds may be synthesized as described in: Hutchinson, A. J. et al., J. Pharmacol. ExD. Ther., vol. 251, pp. 47-55 (1989); Olsson, R. A. et al., J. Med. Chem., vol. 29, pp. 1683-1689 (1986); Bridges, A. J. et al., J. Med.

Chem., vol. 31, pp. 1282-1285 (1988); Hutchinson, A. J. et al., J. Med. Chem., vol. 33, pp. 1919-1924 (1990); Ukena, M. et al., J. Med. Chem., vol. 34, pp. 1334-1339 (1991); Francis, J. E. et al., J. Med. Chem., vol. 34, pp. 2570-2579 (1991); Yoneyama, F. et al., Eur. J. Pharmacol., vol. 213, pp. 199-204  
5 (1992); Peet, N. P. et al., J. Med. Chem., vol. 35, pp. 3263-3269 (1992); and Cristalli, G. et al., J. Med. Chem., vol. 35, pp. 2363-2368 (1992); all of which are incorporated herein by reference.

The present method includes the administration of a Type IV phosphodiesterase (PDE) inhibitor in combination with the compound of  
10 formula (I). Examples of Type IV phosphodiesterase inhibitors include those disclosed in U.S. Patent No. 4,193,926, WO 92-079778, and Molnar-Kimber, K. L. et al., J. Immunol., vol. 150, p. 295A (1993), all of which are incorporated herein by reference.

Specifically, the suitable Type IV phosphodiesterase (PDE) inhibitors  
15 include racemic and optically active 4-(polyalkoxyphenyl)-2-pyrrolidones of the general formula (V)



(disclosed and described in U.S. Patent No. 4,193,926) wherein R<sup>18</sup> and R<sup>19</sup> each are alike or different and are hydrocarbon radicals having up to 18 carbon atoms  
20 with at least one being other than methyl, a heterocyclic ring, or alkyl of 1-5 carbon atoms which is substituted by one or more of halogen atoms, hydroxy, carboxy, alkoxy, alkoxycarbonyl or an amino group or amino.

Examples of hydrocarbon R<sup>18</sup> and R<sup>19</sup> groups are saturated and unsaturated, straight-chain and branched alkyl of 1-18, preferably 1-5, carbon  
25 atoms, cycloalkyl and cycloalkylalkyl, preferably of 3-7 carbon atoms, and aryl and aralkyl, preferably of 6-10 carbon atoms, especially monocyclic.

Examples of alkyl are methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, pentyl, 2-methylbutyl, 2,2-dimethylpropyl, hexyl, heptyl, octyl, nonyl, 1,2-dimethylheptyl, decyl, undecyl, dodecyl and stearyl, with the proviso that when one of R<sup>18</sup> and R<sup>19</sup> is methyl, the other is a value other than methyl.

- 5 Examples of unsaturated alkyl groups are alkenyl and alkynyl, e.g., vinyl, 1-propenyl, 2-propenyl, 2-propynyl and 3-methyl-2-propenyl.

Examples of cycloalkyl and cycloalkylalkyl which preferably contain a total of 3-7 carbon atoms are cyclopropyl, cyclopropylmethyl, cyclopentyl and cyclohexyl.

- 10 Examples of aryl and aralkyl are phenyl and benzyl, which are preferred, and tolyl, xylyl, naphthyl, phenethyl and 3phenylpropyl.

- Examples of heterocyclic R<sup>18</sup> and R<sup>19</sup> groups are those wherein the heterocyclic ring is saturated with 5 or 6 ring members and has a single O, S or N atom as the hetero atom, e.g., 2- and 3-tetrahydrofuryl, 2- and 3-  
15 tetrahydropyranyl, 2- and 3-tetrahydrothiophenyl, pyrrolidino, 2- and 3-pyrrolidyl, piperidino, 2-, 3- and 4-piperidyl, and the corresponding N-alkyl-pyrrolidyl and piperidyl wherein alkyl is of 1-4 carbon atoms. Equivalents are heterocyclic rings having fewer or more, e.g., 4 and 7, ring members, and one or more additional hetero atoms as ring members, e.g., morpholino, piperazino and  
20 N-alkylpiperazino.

- Examples of substituted alkyl R<sup>18</sup> and R<sup>19</sup> groups, preferably of 1-5 carbon atoms, are those mono- or polysubstituted, for example, by halogen, especially fluorine, chlorine and bromine. Specific examples of such halogen-substituted alkyl are 2-chloroethyl, 3-chloropropyl, 4-bromobutyl,  
25 difluoromethyl, trifluoromethyl, 1,1,2-trifluoro-2-chloroethyl, 3,3,3-trifluoropropyl, 2,2,3,3,3-pentafluoropropyl and 1,1,1,3,3,3-hexafluoro-2-propyl. Examples of other suitable substituents for such alkyl groups are hydroxy groups, e.g., 2-hydroxyethyl or 3-hydroxypropyl; carboxy groups, e.g., carboxymethyl or carboxyethyl; alkoxy groups, wherein each alkoxy group  
30 contains 1-5 carbon atoms, e.g., ethoxymethyl, isopropoxymethyl, 2-methoxyethyl, 2-isopropoxyethyl, 2-butoxyethyl, 2-isobutyloxyethyl, and 3-pentoxypentyl.

Also suitable as preferably terminal-positioned substituents on alkyl groups of 1-5 carbon atoms are alkoxycarbonyl of 1-5 carbon atoms in the alkoxy group. Examples of such alkoxycarbonyl substituted alkyl groups are ethoxycarbonylmethyl and 2-butoxycarbonylethyl.

- 5 Alkyl groups of 1-5 carbon atoms can also be substituted, e.g., in the  $\beta$ ,  $\gamma$  and preferably terminal position with amino groups wherein the nitrogen atom optionally is mono- or disubstituted by alkyl, preferably of 1-5 carbon atoms, or is part of a 4- to 7-membered ring.

Rolipram and its analogues are specific examples of preferred Type IV  
10 phosphodiesterase inhibitors.

Examples of inflammatory diseases which may be treated according to the present invention include:

- autoimmune diseases such as lupus erythematosus, multiple sclerosis, type I diabetes mellitus, Crohn's disease, ulcerative colitis, inflammatory bowel  
15 disease, osteoporosis, arthritis, allergic diseases such as asthma, infectious diseases such as sepsis, septic shock, infectious arthritis, endotoxic shock, gram negative shock, toxic shock, cerebral malaria, bacterial meningitis, adult respiratory distress syndrome (ARDS), TNF $\alpha$ -enhanced HIV replication and TNF $\alpha$  inhibition of reverse transcriptase inhibitor activity, wasting diseases  
20 (cachexia secondary to cancer and HIV), skin diseases like psoriasis, contact dermatitis, eczema, infectious skin ulcers, cellulitis, organ transplant rejection (including bone marrow, kidney, liver, lung, heart, skin rejection), graft versus host disease, adverse effects from amphotericin B treatment, adverse effects from interleukin-2 treatment, adverse effects from OKT3 treatment, adverse effects  
25 from GM-CSF treatment, adverse effects of cyclosporine treatment and adverse effects of aminoglycoside treatment, ischemia, mucositis, infertility from endometriosis, circulatory diseases induced or exacerbated by an inflammatory response such as atherosclerosis, peripheral vascular disease, restenosis following angioplasty, inflammatory aortic aneurysm, ischemia/reperfusion  
30 damage, vasculitis, stroke, congestive heart failure, hemorrhagic shock, vasospasm following subarachnoid hemorrhage, vasospasm following cerebrovascular accident, pleuritis, pericarditis, and encephalitis.



The exact dosage of the compound of formula (I) to be administered will, of course, depend on the size and condition of the patient being treated, the exact condition being treated, and the identity of the particular compound of formula (I) being administered. However, a suitable dosage of the compound of formula (I) is 0.5 to 100  $\mu\text{g/kg}$  of body weight, preferably 1 to 10  $\mu\text{g/kg}$  of body weight. Typically, the compound of formula (I) will be administered from 1 to 8, preferably 1 to 4, times per day.

The preferred mode of administration of the compound of formula (I) may also depend on the exact condition being treated. However, most typically, the mode of administration will be oral, topical, intravenous, parenteral, subcutaneous, or intramuscular injection.

Of course, it is to be understood that the compound of formula (I) may be administered in the form of a pharmaceutically acceptable salt. Examples of such salts include acid addition salts. Preferred pharmaceutically acceptable addition salts include salts of mineral acids, for example, hydrochloric acid, sulfuric acid, nitric acid, and the like; salts of monobasic carboxylic acids, such as, for example, acetic acid, propionic acid, and the like; salts of dibasic carboxylic acids, such as maleic acid, fumaric acid, oxalic acid, and the like; and salts of tribasic carboxylic acids, such as carboxysuccinic acid, citric acid, and the like. In the compounds of formula (I) in which R is  $-\text{CO}_2\text{H}$ , the salt may be derived by replacing the acidic proton of the  $-\text{CO}_2\text{H}$  group with a cation such as  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{NH}_4^+$  mono-, di-, tri- or tetra( $\text{C}_{1-4}$ -alkyl)ammonium, or mono-, di-, tri-, or tetra( $\text{C}_{2-4}$ -alkanol)ammonium.

It is also to be understood that many of the compounds of formula (I) may exist as various isomers, enantiomers, and diastereomers and that the present invention encompasses the administration of a single isomer, enantiomer, or diastereomer in addition to the administration of mixtures of isomers, enantiomers, or diastereomers.

The compounds of formula (I) can be administered orally, for example, with an inert diluent with an edible carrier. They can be enclosed in gelatin capsules or compressed into tablets. For the purpose of oral therapeutic administration, the compounds can be incorporated with excipients and used in the form of tablets, troches, capsules, elixirs, suspensions, syrups, waters,

chewing gums, and the like. These preparations should contain at least 0.5% by weight of the compound of formula (I), but the amount can be varied depending upon the particular form and can conveniently be between 4.0% to about 70% by weight of the unit dosage. The amount of the compound of formula (I) in such  
5 compositions is such that a suitable dosage will be obtained. Preferred compositions and preparations according to the present invention are prepared so that an oral dosage unit form contains between about 30  $\mu$ g and about 5 mg, preferably between 50 to 500  $\mu$ g, of active compound.

Tablets, pills, capsules, troches, and the like can contain the following  
10 ingredients: a binder, such as microcrystalline cellulose, gum tragacanth or gelatin; an excipient, such as starch or lactose; a disintegrating agent, such as alginic acid, Primogel, corn starch, and the like; a lubricant, such as magnesium stearate or Sterotes; a glidant, such as colloidal silicon dioxide; a sweetening agent, such as sucrose, saccharin or aspartame; or flavoring agent, such as  
15 peppermint, methyl salicylate, or orange flavoring. When the dosage unit form is a capsule it can contain, in addition to the compound of formula (I), a liquid carrier, such as a fatty oil.

Other dosage unit forms can contain other materials that modify the physical form of the dosage unit, for example, as coatings. Thus, tablets or pills  
20 can be coated with sugar, shellac, or other enteric coating agents. A syrup may contain, in addition to the active compounds, sucrose as a sweetening agent and preservatives, dyes, colorings, and flavors. Materials used in preparing these compositions should be pharmaceutically pure and nontoxic in the amounts used.

For purposes of parenteral therapeutic administration, the compounds of  
25 formula (I) can be incorporated into a solution or suspension. These preparations should contain at least 0.1% of the aforesaid compound, but may be varied between 0.5% and about 50% of the weight thereof. The amount of active compound in such compositions is such that a suitable dosage will be obtained. Preferred compositions and preparations according to the present invention are  
30 prepared so that a parenteral dosage unit contains between 30  $\mu$ g to 5 mg, preferably between 50 to 500  $\mu$ g, of the compound of formula (I).

Solutions or suspensions of the compounds of formula (I) can also include the following components: a sterile diluent, such as water for injection,

saline solution, fixed oils, polyethylene glycols, glycerine, propylene glycol or other synthetic solvents: antibacterial agents, such as benzyl alcohol or methyl parabens; antioxidants, such as ascorbic acid or sodium bisulfite; chelating agents, such as ethylenediaminetetraacetic acid; buffers, such as acetates, citrates or phosphates; and agents for the adjustment of tonicity, such as sodium chloride or dextrose. The parenteral preparation can be enclosed in ampoules, disposable syringes or multiple dose vials made of glass or plastic.

Effective amounts of the Type IV phosphodiesterase inhibitor can be administered to a subject by any one of various methods, for example, orally as in a capsule or tablets, topically, or parenterally in the form of sterile solutions. The Type IV phosphodiesterase inhibitors, while effective themselves, can be formulated and administered in the form of their pharmaceutically acceptable addition salts for purposes of stability, convenience of crystallization, increased solubility, and the like.

Preferred pharmaceutically acceptable addition salts include salts of mineral acids, for example, hydrochloric acid, sulfuric acid, nitric acid, and the like; salts of monobasic carboxylic acids, such as, for example, acetic acid, propionic acid, and the like; salts of dibasic carboxylic acids, such as maleic acid, fumaric acid, oxalic acid, and the like; and salts of tribasic carboxylic acids, such as carboxysuccinic acid, citric acid, and the like.

The Type IV phosphodiesterase may be administered in the form of a pharmaceutical composition similar to those described above in the context of the compound of formula (I).

While dosage values will vary with the specific disease condition to be alleviated, good results are achieved when the Type IV phosphodiesterase inhibitor is administered to a subject requiring such treatment as an effective oral, parenteral or intravenous dose as described below.

For oral administration, the amount of active agent per oral dosage unit usually is 0.1-20 mg, preferably 0.5-10 mg. The daily dosage is usually 0.1-50 mg, preferably 1-30 mg p.o. For parenteral application, the amount of active agent per dosage unit is usually 0.005-10 mg, preferably 0.01-5 mg. The daily dosage is usually 0.01-20 mg, preferably 0.02-5 mg i.v. or i.m.

With topical administration, dosage levels and their related procedures would be consistent with those known in the art, such as those dosage levels and procedures described in U.S. Patent No. 5,565,462 to Eitan et al., which is incorporated herein by reference.

5 It is to be understood, however, that for any particular subject, specific dosage regimens should be adjusted to the individual need and the professional judgment of the person administering or supervising the administration of the Type IV phosphodiesterase inhibitor. It is to be further understood that the dosages set forth herein are exemplary only and that they do not, to any extent,  
10 limit the scope or practice of the present invention.

In a particularly preferred embodiment, the compound of formula (I) and the Type IV phosphodiesterase inhibitor are coadministered together in a single dosage unit. The compound of formula (I) and the Type IV phosphodiesterase inhibitor may be administered in the same type of pharmaceutical composition as  
15 those described above in the context of the compound of formula (I).

By coadministering a Type IV phosphodiesterase inhibitor with the agonist of the  $A_{2A}$  adenosine receptor, it is possible to dramatically lower the dosage of the  $A_{2A}$  adenosine receptor agonist and the Type IV phosphodiesterase inhibitor due to a synergistic effect of the two agents. Thus, in the embodiment  
20 involving coadministration of the  $A_{2A}$  adenosine receptor agonist with the Type IV phosphodiesterase inhibitor, the dosage of the  $A_{2A}$  adenosine receptor agonist may be reduced by a factor of 5 to 10 from the dosage used when no Type IV phosphodiesterase inhibitor is administered. This reduces the possibility of side effects.

25 The present invention will now be described in more detail in the context of the coadministration of WRC-0470, WRC-0474[SHA 211], WRC-0090 or WRC-0018 and rolipram. However, it is to be understood that the present invention may be practiced with other compounds of formula (I) and other Type IV phosphodiesterase inhibitors of formula (V).

30 The present studies establish that anti-inflammatory doses have no toxic effects in animals; the effect of WRC-0470 to inhibit neutrophil activation is synergistic with rolipram; and intravenous infusion of WRC-0470 profoundly inhibits extravasation of neutrophils in an animal model of inflammation, an

action also synergistic with rolipram. Further, the present studies establish that activation of A<sub>2A</sub> receptors on human monocytes strongly inhibits TNF $\alpha$  (an inflammatory cytokine) release. This mechanism further contributes to the anti-inflammatory action of the A<sub>2A</sub> adenosine receptor agonists of the present invention.

Other features of the invention will become apparent in the course of the following descriptions of exemplary embodiments which are given for illustration of the invention and are not intended to be limiting thereof.

### **Examples**

#### 10 Materials and Methods

Materials. f-Met-Leu-Phe(fMLP), luminol, and trypan blue were from Sigma Chemical. Ficoll-hypaque was purchased from Flow Laboratories (McLean, VA) and Los Alamos Diagnostics (Los Alamos, NM). Hanks balanced salt solution (HBSS), and limulus amebocyte lysate assay kit were from Whittaker Bioproducts (Walkersville, MD). Human serum albumin (HSA) was from Cutter Biological (Elkhart, IN). Recombinant human tumor necrosis factor-alpha was supplied by Dianippon Pharmaceutical Co. Ltd. (Osaka, Japan). ZM241385 was a gift of Dr. Simon Poucher, Zeneca Pharmaceuticals (Cheshire, England).

20 Leukocyte Preparation. Purified PMN (~98% PMN and >95% viable by trypan blue exclusion) containing <1 platelet per 5 PMN and <50 pg/ml endotoxin (limulus amebocyte lysate assay) were obtained from normal heparinized (10 Units/ml) venous blood by a one step Ficoll-hypaque separation procedure (Ferrante, A. et al., J. Immunol. Meth., vol. 36, p. 109 (1980)).

25 Residual RBC were lysed by hypotonic lysis with iced 3 ml 0.22% sodium chloride solution for 45 seconds followed by 0.88 ml of 3% sodium chloride solution.

Chemiluminescence. Luminol-enhanced chemiluminescence, a measure of neutrophil oxidative activity, is dependent upon both superoxide production and mobilization of the granule enzyme myeloperoxidase. The light is emitted from unstable high-energy oxygen species generated by activated neutrophils. Purified PMN ( $5 \times 10^5$ /ml) were incubated in HBSS containing 0.1% human serum albumin (1 ml) with or without adenosine, adenosine analogs, and TNF $\alpha$



(1 U/mL) for 30 minutes at 37°C in a shaking water bath. Then luminol ( $1 \times 10^{-4}$  M) enhanced f-met-leu-phe (1  $\mu$ M) stimulated chemiluminescence was read with a Chronolog Photometer (Chrono-log Corp., Havertown, PA) at 37°C for 8 minutes. Chemiluminescence is reported as relative peak light emitted (= height of the curve) compared to samples with TNF and without adenosine or adenosine analogs. WRC-0474[SHA 211] was 10 times more potent than either adenosine (ADO) or CGS21680 in decrease TNF $\alpha$ -primed f-met-leu-phe-stimulated PMN chemiluminescence (see Figure 1).

#### Synergy of A<sub>2A</sub> Adenosine Receptor Agonist and Phosphodiesterase

10 Inhibitors. The synergy between WRC-0474[SHA 211] and 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone (rolipram) was examined by measuring the effect of combined WRC-0474[SHA 211] and rolipram on TNF-primed f-met-leu-phe-stimulated suspended neutrophil superoxide release and on the oxidative burst of neutrophils adhering to matrix proteins (in this model the PMN oxidative burst is enhanced by small concentrations of TNF $\alpha$  [e.g., 1 U/ml] when added prior to the addition of a second stimulus such as the peptide f-met-leu-phe).

Suspended PMN Superoxide Release. Human PMN ( $1 \times 10^6$ /ml) from Ficoll-hypaque separation were primed for 30 minutes (37°C) with or without rhTNF (10 U/ml), with adenosine deaminase (1 U/ml), and with or without 4-(3-cyclopentyloxy-4-methoxyphenyl)-2-pyrrolidone and SHA 211. Cytochrome c (120  $\mu$ M), catalase (0.062 mg/ml) and fMLP (100 nM) were added and the samples incubated for 10 minutes more at 37°C. SOD (200 U/ml) was added to matched samples. The samples were iced and centrifuged (2000 g  $\times$  10 minutes). The optical density of the supernatants were read at 550 nm against the matched SOD samples, and the nmoles of SOD-inhibitable superoxide released in 10 minutes were calculated.

A synergistic effect of WRC-0474[SHA 211] and rolipram in decreasing the TNF $\alpha$ -primed fMLP-stimulated PMN oxidative burst was observed (see Figure 2).

TNF $\alpha$ -stimulated superoxide release of PMN adherent to a matrix protein (fibrinogen) coated surface. Human PMN ( $1 \times 10^6$ /ml) from Ficoll-hypaque separation were incubated for 90 minutes in 1 ml of Hanks balanced salt solution



containing 0.1% human serum albumin, cytochrome c (120  $\mu$ M), and catalase (0.062 mg/ml) in the presence and absence of rhTNF (1 U/ml), WRC-0474[SHA 211] (10 nM) and rolipram (100 nM) in a tissue culture well which had been coated overnight with human fibrinogen. SOD (200 U/ml) was added to  
5 matched samples. The supernatants were iced and centrifuged (2000 g  $\times$  10 minutes) to remove any remaining suspended cells, and the optical density of the supernatants were read at 550 nm against the matched SOD samples, and the nmoles of SOD-inhibitable superoxide released in 90 minutes were calculated.

A synergistic effect of WRC-0474[SHA 211] and rolipram in decreasing  
10 the TNF $\alpha$ -stimulated release of superoxide from PMN adherent to fibrinogen was observed (see Figure 3).

Effect of WRC-0474[SHA 211] with and without rolipram on TNF-  
Stimulated PMN Adherence to a Fibrinogen-Coated Surface. Cronstein et al., *J.*  
*Immunol.*, vol. 148, p. 2201 (1992) reported that adenosine binding to A<sub>1</sub>  
15 receptors increases PMN adherence to endothelium and matrix proteins and binding to A<sub>2</sub> receptors decreases adherence to these surfaces when the PMN are stimulated with fMLP. Despite this, others have failed to see much of an effect of adenosine (10  $\mu$ M) on TNF $\alpha$ -stimulated PMN adherence to matrix proteins. In contrast, adenosine dramatically decreases the oxidative burst of TNF $\alpha$ -  
20 stimulated PMN adhering to matrix proteins (DeLa Harpe, J., *J. Immunol.*, vol. 143, p. 596 (1989)). The experiments described above establish that WRC-0474[SHA 211] decreases TNF-stimulated oxidative activity of PMN adhering to fibrinogen, especially when combined with rolipram.

PMN adherence to fibrinogen was measured as follows as adapted from  
25 Hanlon, *J. Leukocyte Biol.*, vol. 50, p. 43 (1991). Twenty-four well flat-bottomed tissue culture plates were incubated (37°C) overnight with 0.5 ml of fibrinogen (5 mg/ml) dissolved in 1.5% NaHCO<sub>3</sub>. The plates were emptied and each well washed 2 $\times$  with 1 ml of normal saline. The wells were then filled with 1 ml of HBSS-0.1% human serum albumin containing PMN (1  $\times$  10<sup>6</sup>/ml) with  
30 and without rhTNF $\alpha$  (1 U/ml), adenosine deaminase (ADA) (1 U/ML), WRC-0474[SHA 211] (10 nM), CGS21680 (30 nM), adenosine (100 nM) and rolipram (100 nM). The plates were incubated for 90 minutes at 37°C in 5% CO<sub>2</sub>. Following incubation the tissue culture wells were washed free of non-adherent

cells with normal saline. The adherent monolayer of PMN was lysed with 0.1% triton-X, the amount of lactic dehydrogenase (LDH) released from the monolayer assayed (LDH kit, Sigma Co., St. Louis, MO), and compared to a standard curve relating the LDH content of PMN numbers. The results are  
5 shown in Figure 4.

As a comparison to WRC-0474[SHA 211] (at only 10 nM), CGS21680 (30 nM) decreased TNF-stimulated adherence in the presence of ADA from 38% to 30% adhered ( $p = .004$ ) (see Fig. 4), and ten times as much adenosine (100 nM) decreased adherence to 28% adhered ( $p = .009$  compared to TNF in the  
10 presence of ADA).

Additional effects of adenosine  $A_{2A}$ -agonists on adherent human neutrophil oxidative activity. The bioactivity of test compounds WRC-0474[SHA 211], WRC-0470, WRC-0090 and WRC-0018 were evaluated according to the following method modified from Sullivan, G. W. et al., Int. J. Immunopharmacol., 17, 793-803 (1995). Neutrophils ( $1 \times 10^6/\text{ml}$ ) from Ficoll-hypaque separation were incubated for 90 minutes in 1 ml of Hanks balanced salt solution containing 0.1% human serum albumin, cytochrome c (120  $\mu\text{M}$ ) and catalase (0.062 mg/ml) in the presence and absence of rhTNF $\alpha$  (1 U/ml), WRC-0474[SHA 211], WRC-0470, WRC-0090 and WRC-0018 (3-300 nM), and  
20 rolipram (100 nM) in a tissue culture well which had been coated overnight with human fibrinogen. The supernatants were iced and centrifuged (200 g  $\times$  10 minutes) to remove any remaining suspended cells, and the optical densities of the supernatants were read at 550 nm against matched superoxide dismutase (SOD) (200 U/ml) samples. The nmoles of SOD = inhibitable superoxide  
25 released in 90 minutes were calculated.

Figure 5 shows synergy between  $A_{2A}$  adenosine agonists and rolipram in inhibiting TNF $\alpha$ -stimulated adherent PMN oxidative activity ( $p < 0.05$ ). WRC-0474[SHA 211] (30-300 nM), WRC-0470 (300 nM), WRC-0090 (300 nM) and WRC-0018 (300 nM) combined with rolipram synergistically decreased  
30 superoxide release ( $p < 0.05$ ). All four compounds had some activity in the presence of rolipram. WRC-0474[SHA 211] and WRC-0470 were the most active. Nanomolar concentrations of WRC-0474[SHA 211] resulted in biphasic

activity. All compounds were synergistic with rolipram to decrease TNF $\alpha$ -stimulated adherent PMN oxidative activity.

PMN degranulation (adherent cells). The following methods were adapted from Sullivan, G. W. and G. L. Mandell, *Infect. Immun.*, 30, 272-280 (1980). Neutrophils ( $3.1 \times 10^6$ /ml) from Ficoll-hypaque separation were incubated for 120 minutes in 1 ml of Hanks balanced salt solution containing 0.1% human serum albumin,  $\pm$  rh TNF $\alpha$  (10 U/ml),  $\pm$  WRC-0470 (3-300 nM) and  $\pm$  rolipram (300 nM) in a tissue culture well which had been coated overnight with human fibrinogen. The supernatant fluids with any suspended neutrophils were harvested following incubation, centrifuged ( $2000 \times g$  for 10 minutes) to remove any suspended cells and the cell-free supernatants frozen. Release of lysozyme, a component of neutrophil primary and secondary granules was assayed. Lysis of a suspension of *Micrococcus lysodeikticus* by the "cell-free supernatant" was measured by spectrophotometric analysis (540 nm) to determine the amount of release of granule contents to the surrounding medium.

Results showed that WRC-0470 (300 nM) with rolipram (300 nM) significantly decreased TNF $\alpha$ -stimulated adherent neutrophil degranulation 67%;  $P = 0.027$ . The data indicate that in addition to decreasing TNF $\alpha$ -stimulated PMN adherent and the oxidative burst of these adherent neutrophils, WRC-0470 also decreases degranulation-activated PMN adhering to a biological surface.

PMN oxidative activity in whole blood. The following methods were adapted from Rothe, G. A. et al., *J. Immunol. Meth.*, 138, 133-135 (1991). Heparinized whole blood (0.8 ml) was incubated ( $37^\circ$ ; 30 minutes) with adenosine deaminase (ADA, 1 U/ml), catalase (14,000 U/ml),  $\pm$  dihydrorhodamine 123,  $\pm$  WRC-0470 (3-300 nM),  $\pm$  rolipram (300 nM) and  $\pm$  TNF $\alpha$  (10 U/ml). The primed blood samples were stimulated with fMLP (15 minutes), then iced, the red blood cells lysed with FACS lysing solution (Becton-Dickinson, San Jose, CA), washed and the leukocytes resuspended in phosphate buffered saline (PBS). These samples containing mixed leukocytes were gated for neutrophils by forward and side scatter and the fluorescence of 10,000 neutrophils measured in the FL1 channel of a FACScan (Becton-Dickinson) fluorescence-activated cell sorter.

The results are reported as relative mean fluorescence intensity in Figure 6 of the drawings. WRC-0470 decreased oxidative activity of TNF $\alpha$ -primed fMLP-stimulated neutrophils in whole blood and acted synergistically with rolipram. WRC-0470 (30-300 nM) decreased neutrophil oxidative activity synergistically with rolipram (300 nM) in samples stimulated with fMLP and in blood samples primed with TNF $\alpha$  and then stimulated with fMLP.

Production of TNF $\alpha$  by purified human adherent monocytes. A monocyte-rich monolayer (>95% monocytes) was prepared by incubating 1 ml of the mononuclear leukocyte fraction ( $5 \times 10^5$ /ml) from a Ficoll-hypaque separation in wells of a 24 well tissue culture plate (1 hour; 37°C; 5% CO<sub>2</sub>). The non-adherent leukocytes were removed by washing and culture medium added to the wells (1 ml RPMI 1640 containing 1.5 mM HEPES-1% autologous serum with penicillin and streptomycin (250 U/ml and 250  $\mu$ g/ml, respectively) and ADA (1 U/ml)  $\pm$  WRC-0470 (30-100 nM),  $\pm$  endotoxin (10 ng/ml),  $\pm$  rolipram (300 nM) and  $\pm$  the adenosine A<sub>2A</sub> selective antagonist 4-(2-[7-amino-2-(2-furyl)[1,2,4]-triazolo[2,3a]-[1,3,5]triazinyl-amino]ethyl)-phenol (ZM241385) (50 nM). The samples were incubated for 4 hours (37°C; 5% CO<sub>2</sub>) and the supernatants harvested. Any suspended cells were removed by centrifugation and the cell-free samples frozen (-70°C). TNF $\alpha$  was assayed in the cell-free supernatants by an ELISA kit (Cistron Biotechnology, Pine Brook, NJ).

As shown in Figures 7A and 7B, WRC-0470  $\pm$  rolipram decreased endotoxin-stimulated adherent monocyte production of TNF $\alpha$  ( $P < 0.050$ ). As illustrated in Figure 7B, the A<sub>2A</sub> selective antagonist SM241385 significantly inhibited the effect of WRC-0470 (300 nM) combined with rolipram (300 nM) ( $p = 0.020$ ) on TNF $\alpha$  release from monocytes. Hence, WRC-0470 affects TNF $\alpha$ -stimulated neutrophil activity and decreases endotoxin-stimulated TNF $\alpha$  production by monocytes.

Effects of WRC-0470 and rolipram on the extravasation of white blood cells in a rat model of inflammation. Adult wistar rats (approximately 200 g) were anesthetized with intermuscular injections of ketamine and xylazine. Bacteria meningitis (BM) was induced via intracisternal inoculation of either *E. coli* strain 026:B6LPS (200 ng), cytokines (IL-1 and TNF $\alpha$ , or LPS plus cytokines). The animals were then infused with rolipram and/or WRC-1470



over the duration of the experiment using a Harvard pump. CSF (cerebrospinal fluid) and blood was then sampled at 4 hours postinoculation and alterations in BBBP (blood-brain-barrier permeability) and WBC (white blood cell) counts were determined. CSF and WBC concentrations were determined with standard hemacytometer methods. For assessment of % BBBP, rats were given an intravenous injection of 5  $\mu\text{Ci}$   $^{125}\text{I}$ -labeled bovine serum albumin concomitant with intracisternal inoculation. Equal samples of CSF and blood were read simultaneously in a gamma counter and after subtraction of background radioactivity, % BBBP was calculated by the following formula: % BBBP = (cpm CSF/cpm blood)  $\times$  100. All statistical tests were performed using Instat biostatistical software to compare the post-inoculation samples of experimental rats with the control rats. The statistical tests used to generate p-values were Student's t -test and ANOVA.

Results of the tests are reported in Figures 8 and 9. Infusion of WRC-0470 at a rate of 0.005-1.2  $\mu\text{g/kg/hour}$  inhibited pleocytosis ( $p < 0.05$  as compared to control). The effect of WRC-0470 on BBBP is shown in Figure 9. A significant response is seen with a range of 0.01-0.015  $\mu\text{g/kg/hour}$  ( $p < 0.05$  as compared to control). A rebound effect is noted with the administration of 1.2  $\mu\text{g/kg/hour}$  where % BBBP returned to control. Figure 10 shows the effect of rolipram on CSF pleocytosis in a range of 0-0.01  $\mu\text{g/kg/hour}$  with 0.01  $\mu\text{g/kg/hour}$  inhibiting 99% of the pleocytosis ( $p < 0.05$ ). Rolipram at either 0.01 or 0.005  $\mu\text{g/kg/hour}$  showed significant inhibition of alterations of BBBP ( $p < 0.05$ ), while a dose of 0.002  $\mu\text{g/kg/hour}$  had no significant effect.

The effect of a combination of rolipram and WRC-0470 on CSF WBC pleocytosis is illustrated in Figure 11. Rolipram (0.001  $\mu\text{g/kg/hour}$ ) in combination with WRC-0470 (0.1  $\mu\text{g/kg/hour}$ ) inhibited migration of WBC's ( $200 \pm 70$  WBC/ $\mu\text{l}$ ) into the sub-arachnoid space (SAS) to a greater extent than did either rolipram ( $1,670 \pm 1,273$  WBC/ $\mu\text{l}$ ,  $p < 0.050$ ) or WRC-0470 ( $600 \pm 308$  WBCs/ $\mu\text{l}$ ,  $p < 0.050$ ) alone. The data show a powerful inhibiting effect of WRC-0470 and a synergy with rolipram to prevent inflammation in an animal model.

Application of  $A_{2A}$  adenosine receptors with or without rolipram on balloon angioplasty and gene therapy. Balloon angioplasty is commonly used to

treat coronary artery stenosis. Restenosis following balloon angioplasty (BA) occurs in up to 40% of coronary interventions. Holmes et al., American Journal of Cardiology, 53, 77C-81C (1984). (40%). Restenosis results from a complex interaction of biologic processes, including (i) formation of platelet-rich  
5 thrombus; (ii) release of vasoactive and mitogenic factors causing migration and proliferation of smooth muscle cells (SMC); (iii) macrophage and other inflammatory cell accumulation and foam cell (FC) formation; (iv) production of extracellular matrix; and (v) geometric remodeling. Recently the use of coronary stents and pharmacologic intervention using a chimeric antibody to block the  
10 integrin on platelets have been partially successful in limiting restenosis after percutaneous coronary interventions in man. Topol et al., Lancet, 343, 881-886 (1994). Since inflammatory cell infiltration might be central to the response to injury, and restenotic processes, and adenosine, active via  $A_{2A}$  adenosine receptors, inhibits tissues' inflammatory cell accumulation, we hypothesize that  
15 agonists of  $A_{2A}$  adenosine receptors  $\pm$  Type IV PDE inhibitors will reduce the incidence of restenosis following balloon angioplasty.

In addition, recent advances in local delivery catheters and gene delivery techniques raise the interesting and exciting possibility of administering genes locally into the vessel wall. Nabel et al., Science, 249, 1285-1288 (1990);  
20 Leclerc et al., Journal of Clinical Investigation, 90, 936-944 (1992). Adenoviral-mediated gene transfer affords several advantages over other techniques. However, gene expression is only transient, and has been observed for 7-14 days with diminution or loss of expression by 28 days. Lack of persistence may result from host immune cytolytic responses directed against infected cells. The  
25 inflammatory response generated by the present generation of adenovirus results in neointimal lesion formation and may thus offset the benefit of a therapeutic gene. Newman et al., Journal of Clinical Investigation, 96, 2955-1965 (1995). An  $A_{2A}$  adenosine receptor agonist  $\pm$  a Type IV phosphodiesterase inhibitor in combination with adenovirus may improve the efficiency of gene transfer.

30 Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

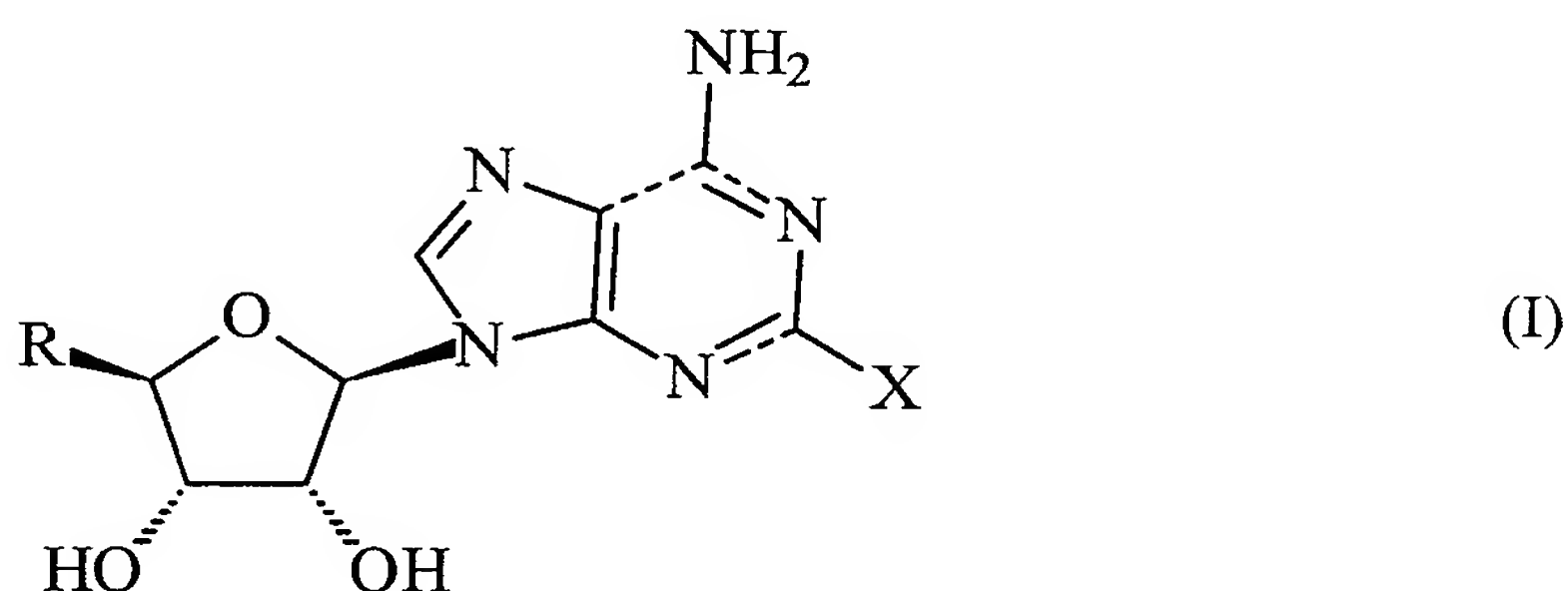


WHAT IS CLAIMED IS:

1. The use of an agonist of an  $A_{2A}$  adenosine receptor in combination with a compound that is a Type IV phosphodiesterase inhibitor, preferably rolipram, a  
5 rolipram derivative, to treat inflammatory disease.

2. A pharmaceutical composition comprising an effective amount of an agonist of an  $A_{2A}$  adenosine receptor in combination with a Type IV phosphodiesterase inhibitor, preferably rolipram or a rolipram derivative or a  
10 rolipram analogue.

3. The pharmaceutical composition of Claim 2, wherein said agonist of an  $A_{2A}$  adenosine receptor has the formula (I)



wherein X is a group selected from the group consisting of  $-OR^1$ ,  $-NR^2R^3$ ,  
15 and  $-NH-N=R^4$ ;

wherein  $R^1$  is  $C_{1-4}$ -alkyl;  $C_{1-4}$ -alkyl substituted with one or more  $C_{1-4}$ -alkoxy groups, halogen (preferably fluorine, chlorine, or bromine), hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, di( $C_{1-4}$ -alkyl)amino groups, or  $C_{6-10}$ -aryl groups (wherein the aryl groups may be substituted with one  
20 or more halogens (preferably fluorine, chlorine, or bromine),  $C_{1-4}$ -alkyl groups, hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, or di( $C_{1-4}$ -alkyl)amino groups;  $C_{6-10}$ -aryl; or  $C_{6-10}$ -aryl substituted with one or more halogens (fluorine, chlorine, or bromine), hydroxy groups, amino groups, mono( $C_{1-4}$ -alkyl)amino groups, or di( $C_{1-4}$ -alkyl)amino groups, or  $C_{1-4}$ -alkyl  
25 groups;

one of  $R^2$  and  $R^3$  has the same meaning as  $R^1$  and the other is hydrogen;

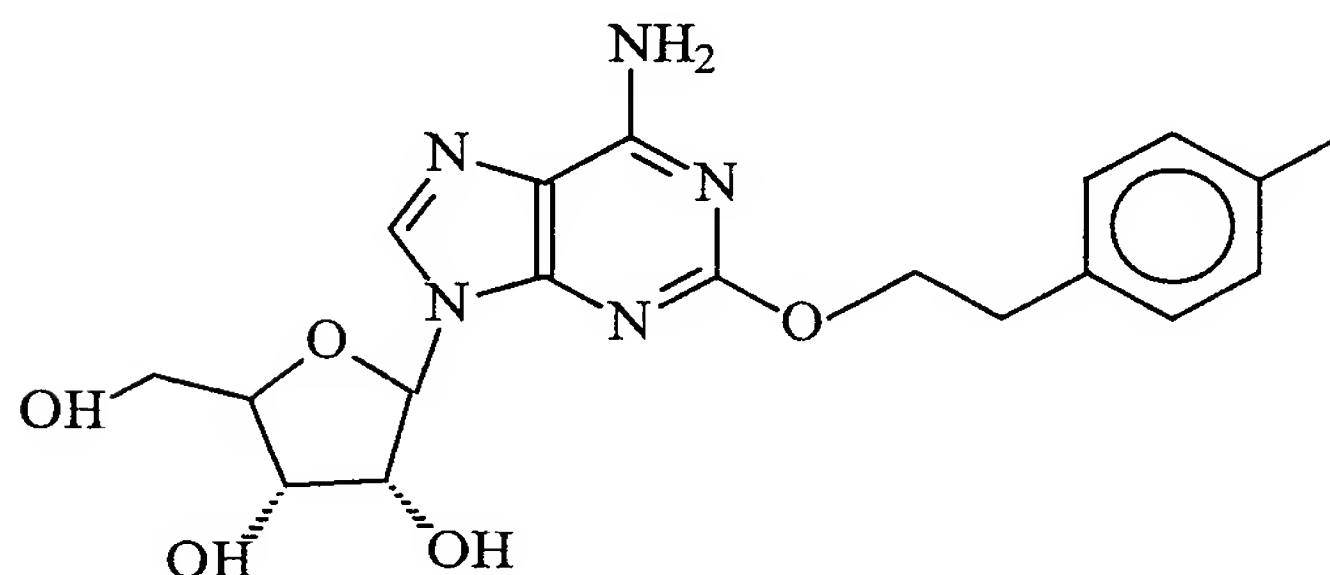
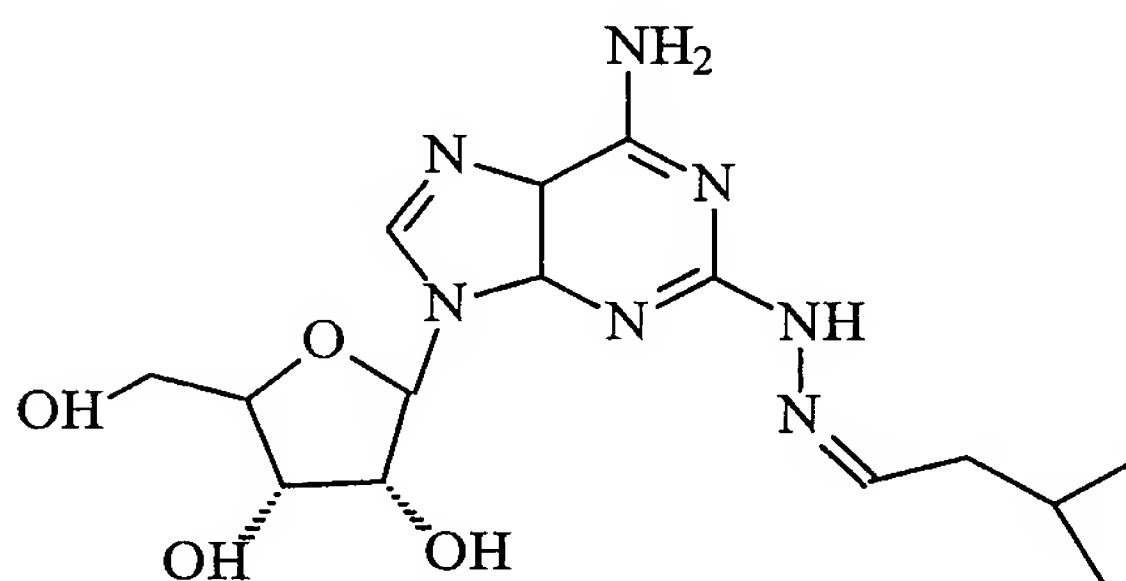
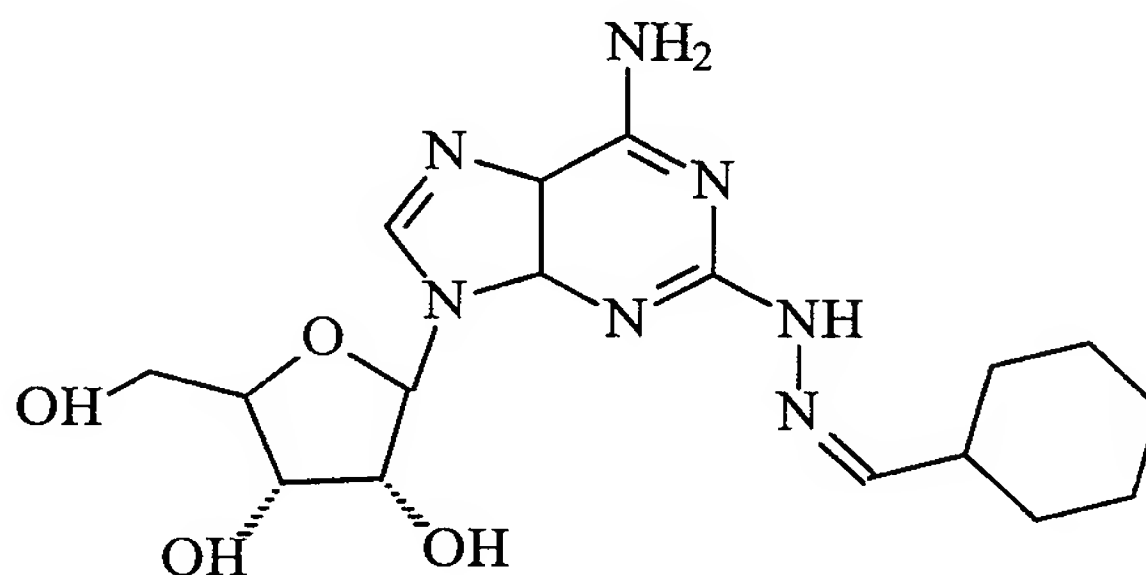
R<sup>4</sup> is a group having the formula



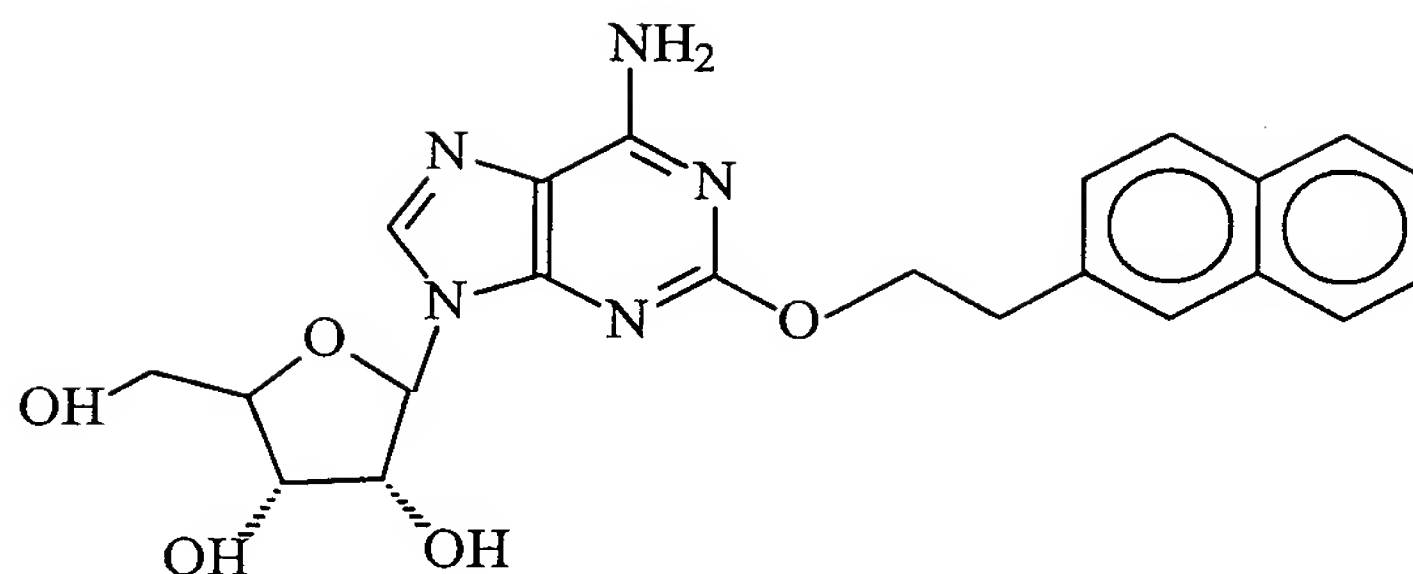
wherein each of R<sup>5</sup> and R<sup>6</sup> independently may be hydrogen, C<sub>3-7</sub>-cycloalkyl, or any of the meanings of R<sup>1</sup>, provided that R<sup>5</sup> and R<sup>6</sup> are not both hydrogen;

5 or a pharmaceutically acceptable salt thereof.

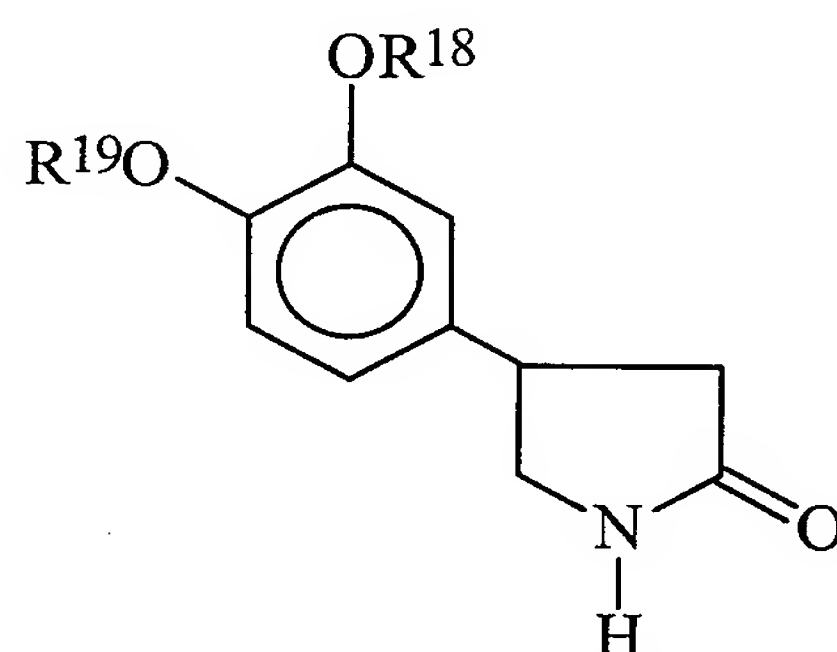
4. The pharmaceutical composition of Claim 2, wherein said agonist of an A<sub>2A</sub> adenosine receptor is selected from the group consisting of



and



5. The pharmaceutical composition of Claim 2, wherein said Type IV  
5 phosphodiesterase inhibitor is a compound having formula (V):



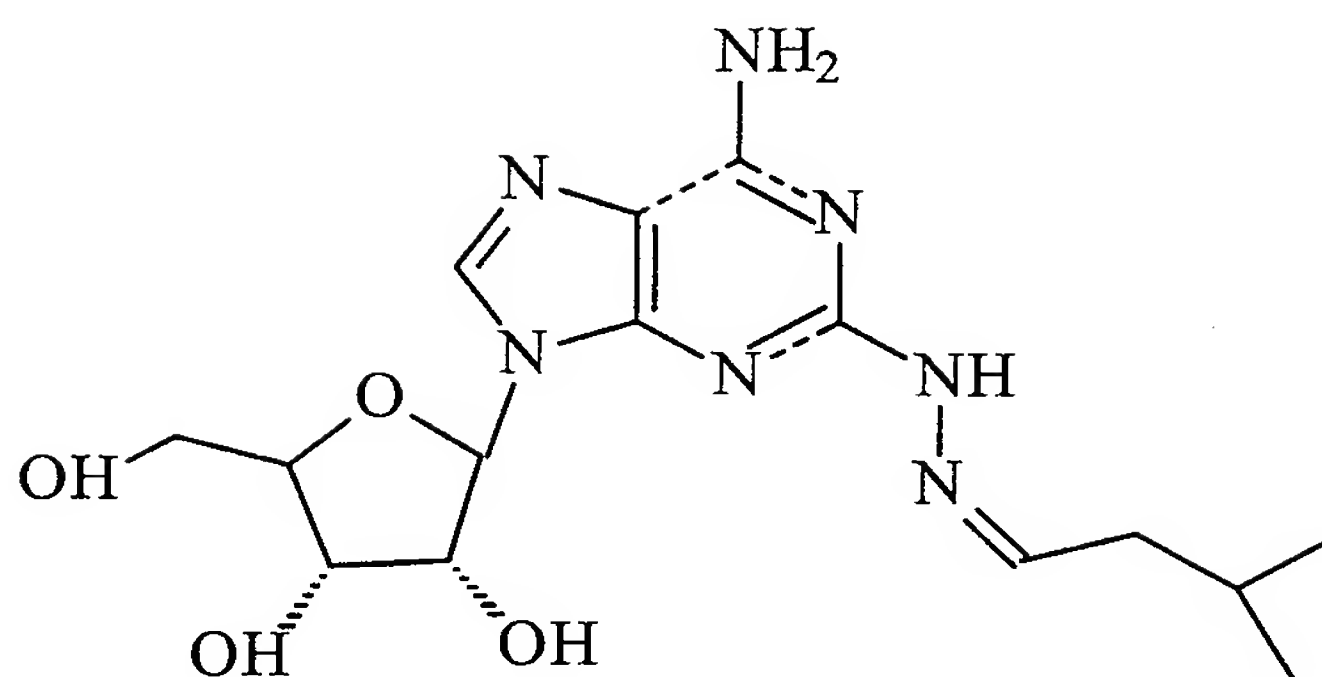
(V)

- wherein  $R^{18}$  and  $R^{19}$  each are alike or different and are hydrocarbon radicals  
having up to 18 carbon atoms with at least one being other than methyl, a  
heterocyclic ring, or alkyl of 1-5 carbon atoms which is substituted by one or  
more of halogen atoms, hydroxy, carboxy, alkoxy, alkoxycarbonyl or an amino  
10 group; amino;  $R'$  is a hydrogen atom, alkyl, aryl or acyl; and X is an oxygen  
atom or a sulfur atom.

6. The pharmaceutical composition of Claim 2, wherein said Type IV  
phosphodiesterase inhibitor is rolipram.

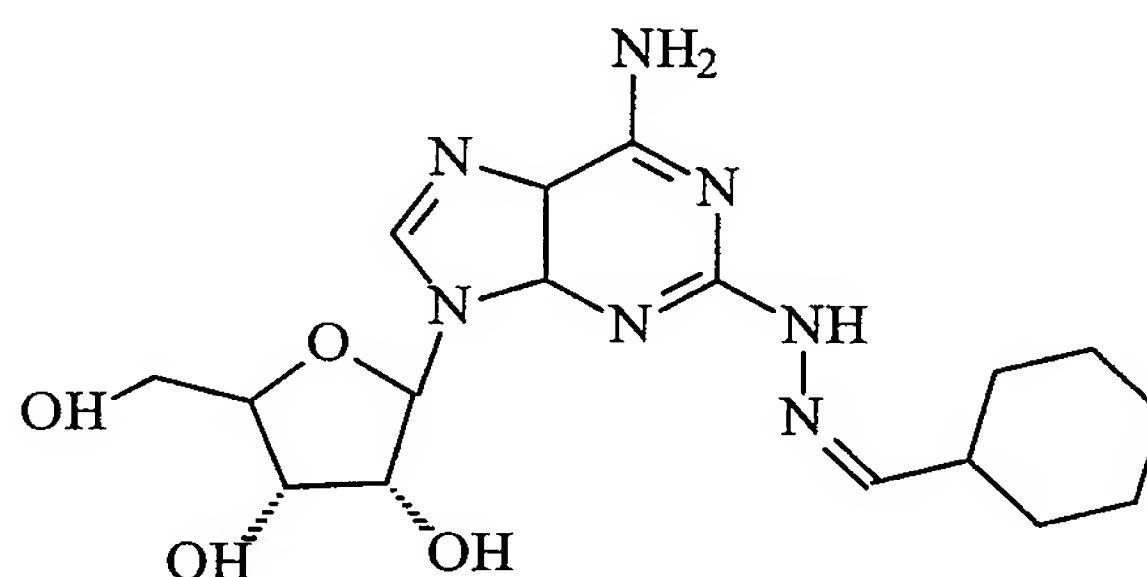
15

7. The pharmaceutical composition of Claim 2, wherein said agonist of an  
 $A_{2A}$  adenosine receptor is



and said Type IV phosphodiesterase inhibitor is rolipram.

8. The pharmaceutical composition of Claim 2, wherein said agonist of an  $A_{2A}$  adenosine receptor is



5 and said Type IV phosphodiesterase inhibitor is rolipram.

9. The use of an agonist of an  $A_{2A}$  adenosine receptor in combination with a Type IV phosphodiesterase inhibitor, preferably rolipram or a rolipram derivative, during and for a limited time after balloon angioplasty to reduce  
10 frequency and extent of restenosis.

10. The use of an agonist of an  $A_{2A}$  adenosine receptor in combination with a Type IV phosphodiesterase inhibitor, preferably rolipram or a rolipram derivative, in conjunction with a gene delivery modality to limit inflammation  
15 and thereby improve efficiency and stability of gene therapy.

11. The use of claim 10, wherein said gene delivery modality is viruses and lipid vesicles.

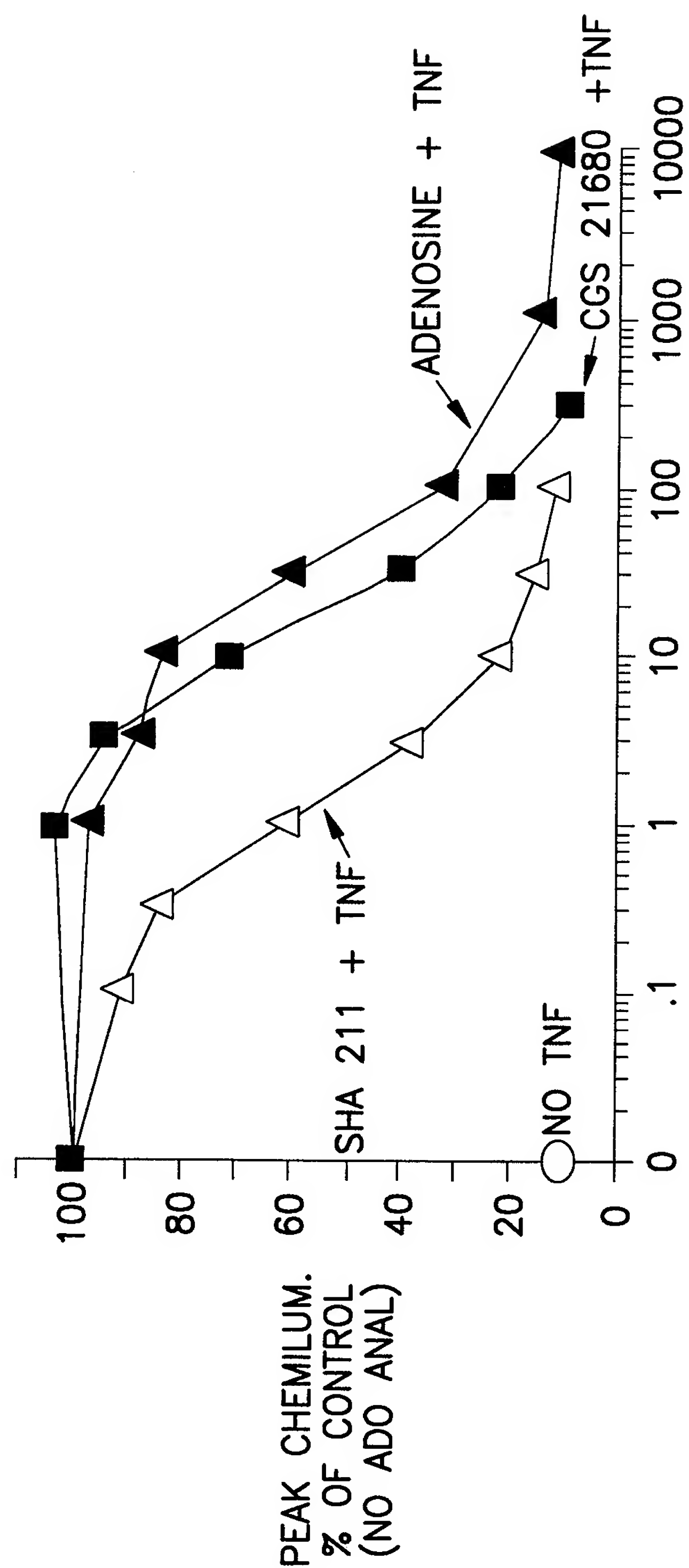


FIGURE 1



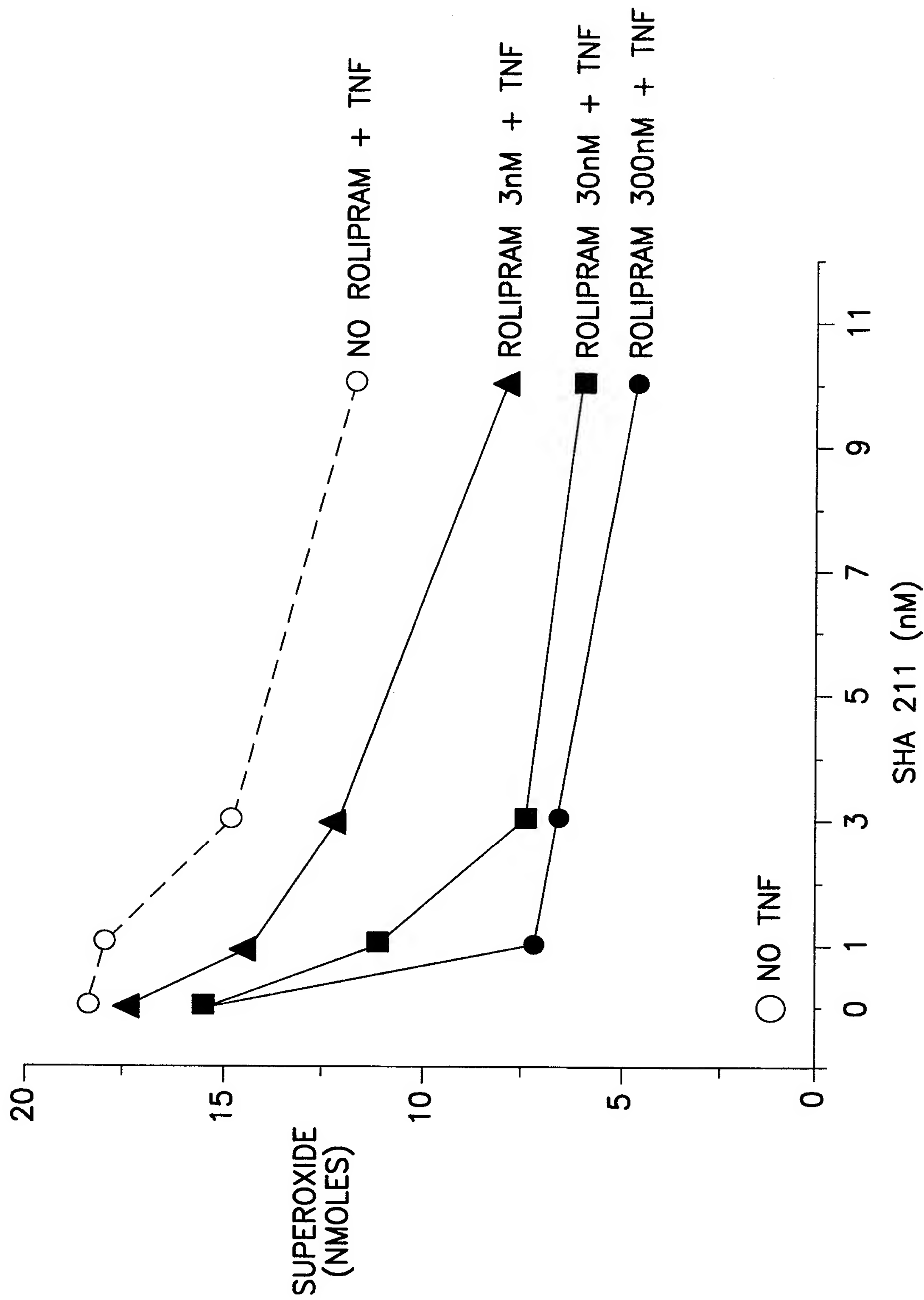


FIGURE 2

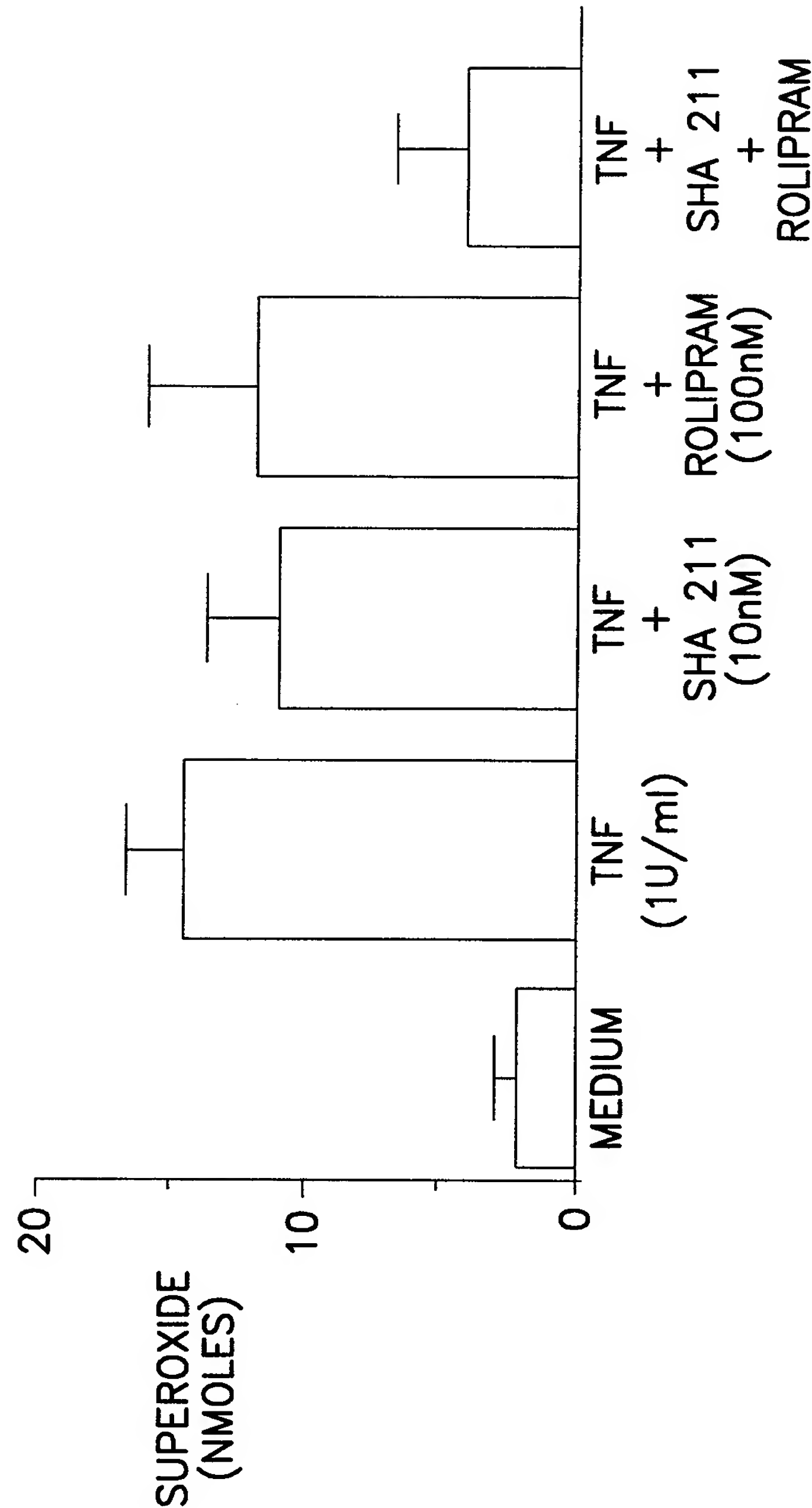


FIGURE 3

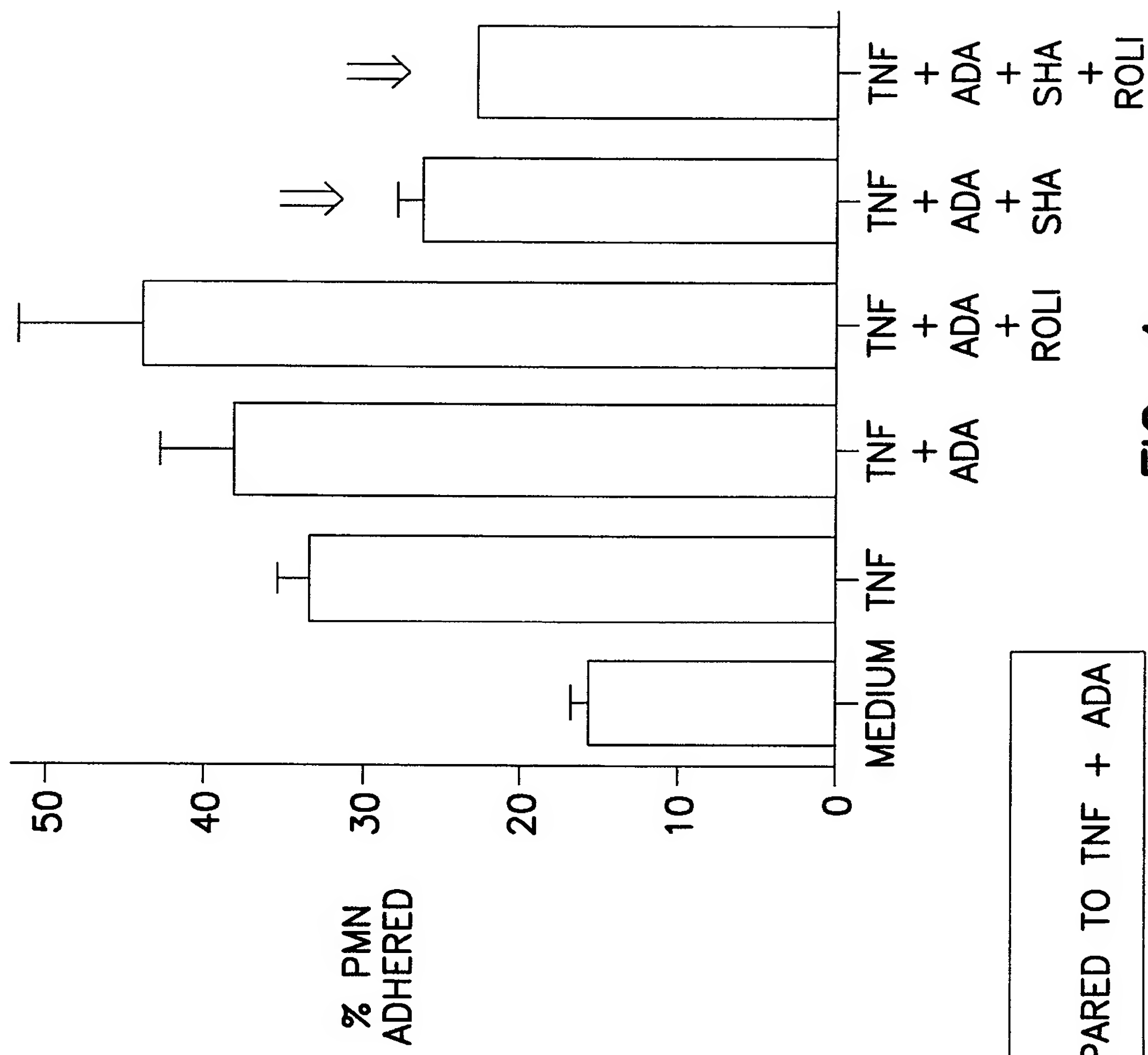
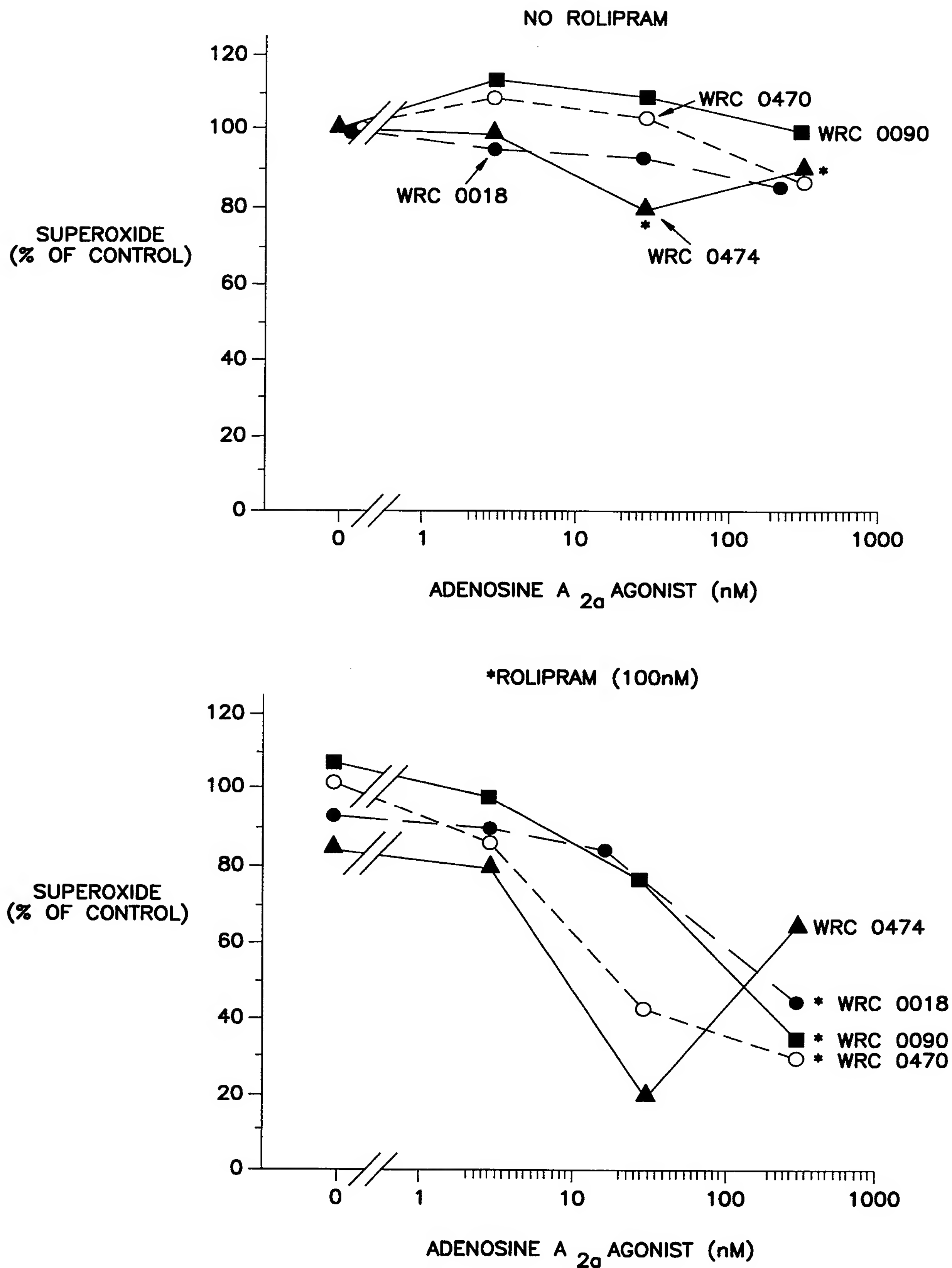


FIG. 4

⇓ P<.05 COMPARED TO TNF + ADA



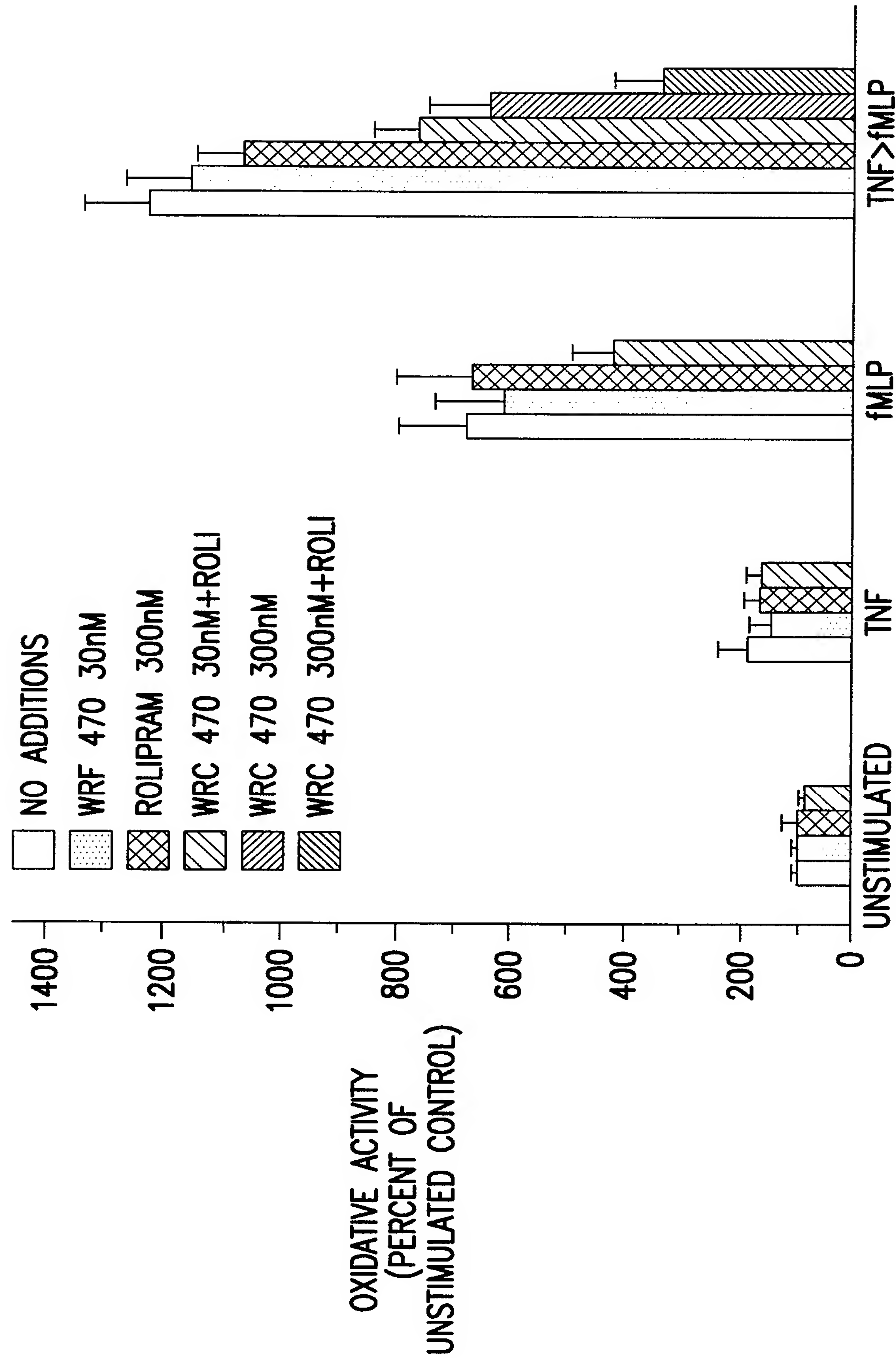


FIGURE 6

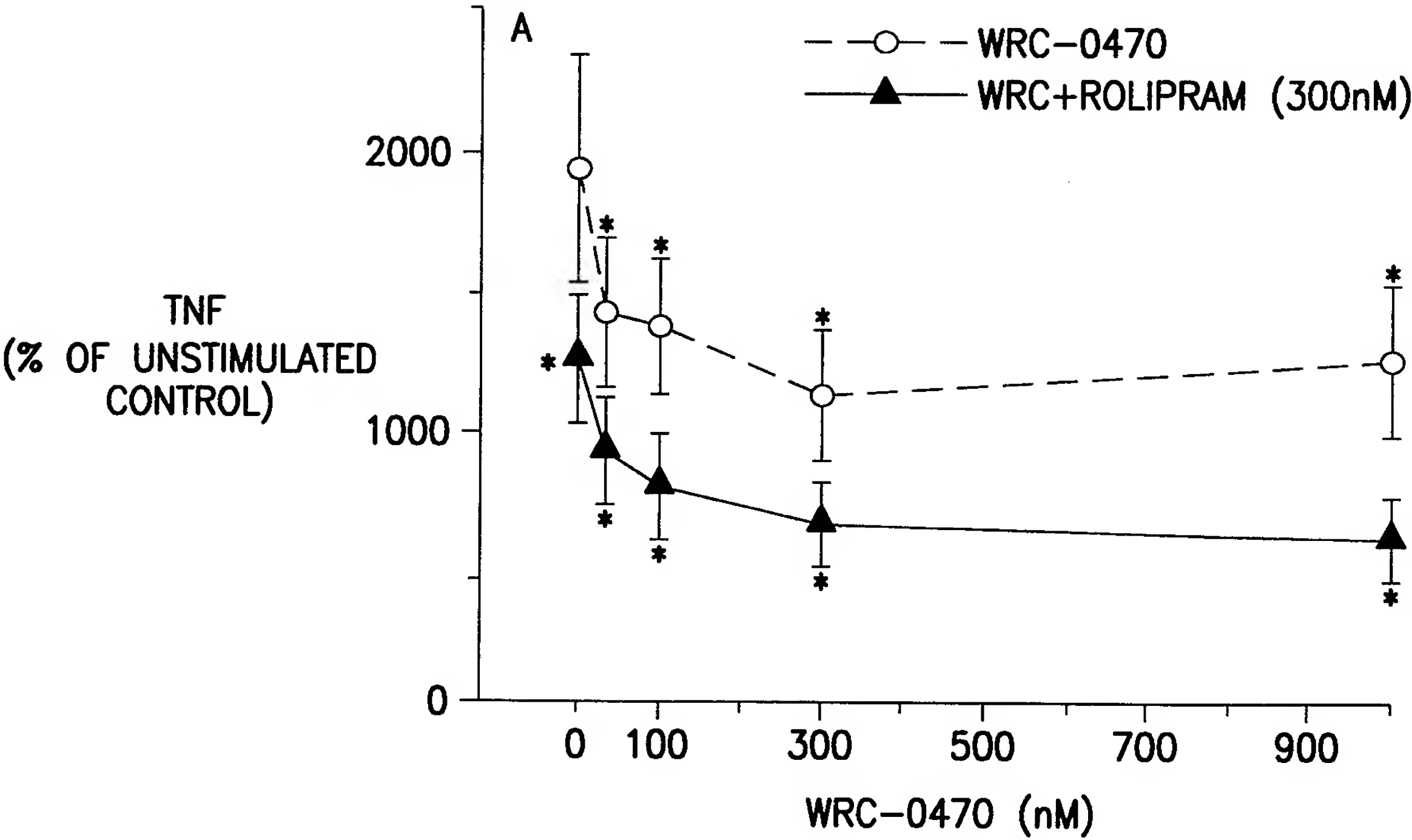


FIGURE 7A

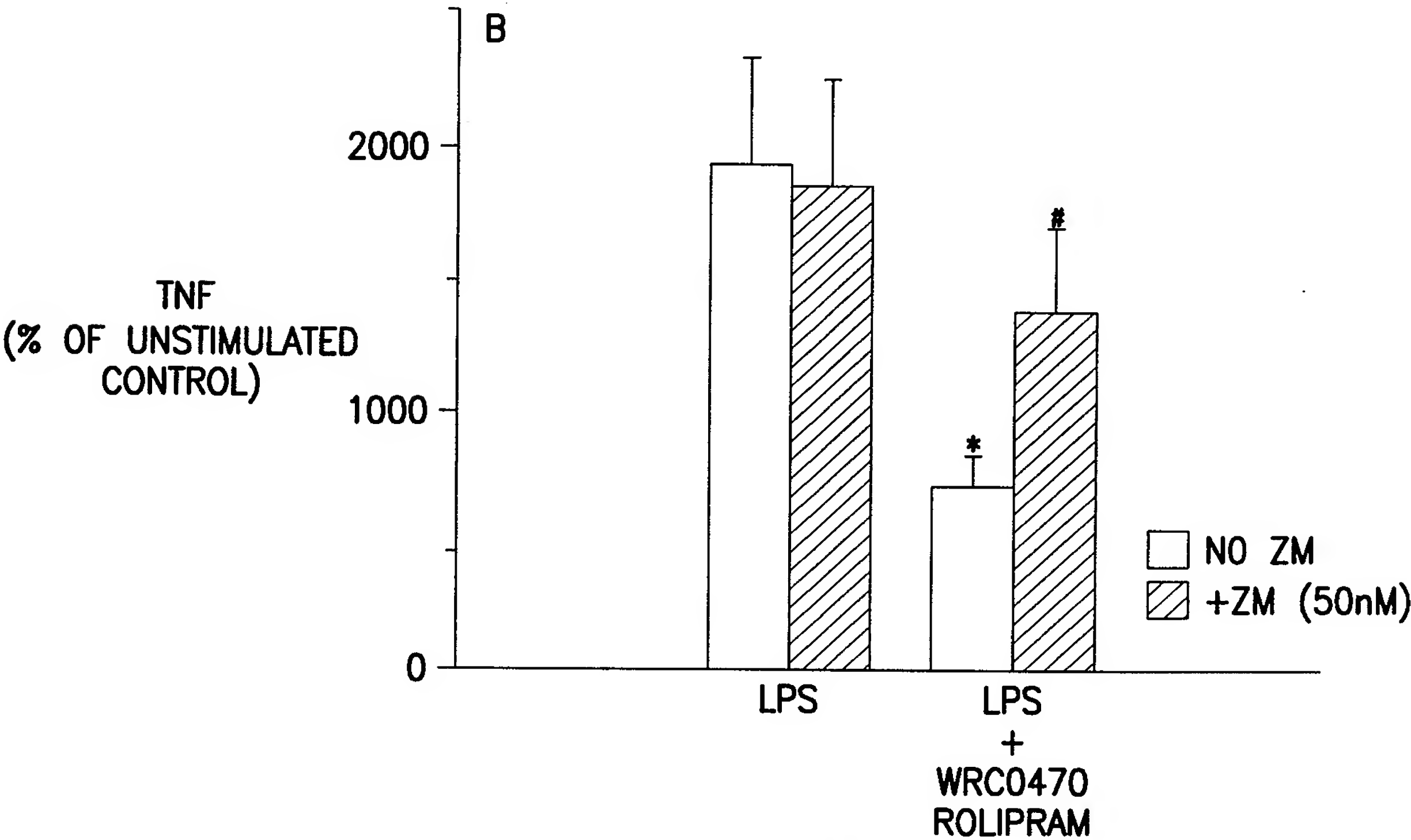


FIGURE 7B

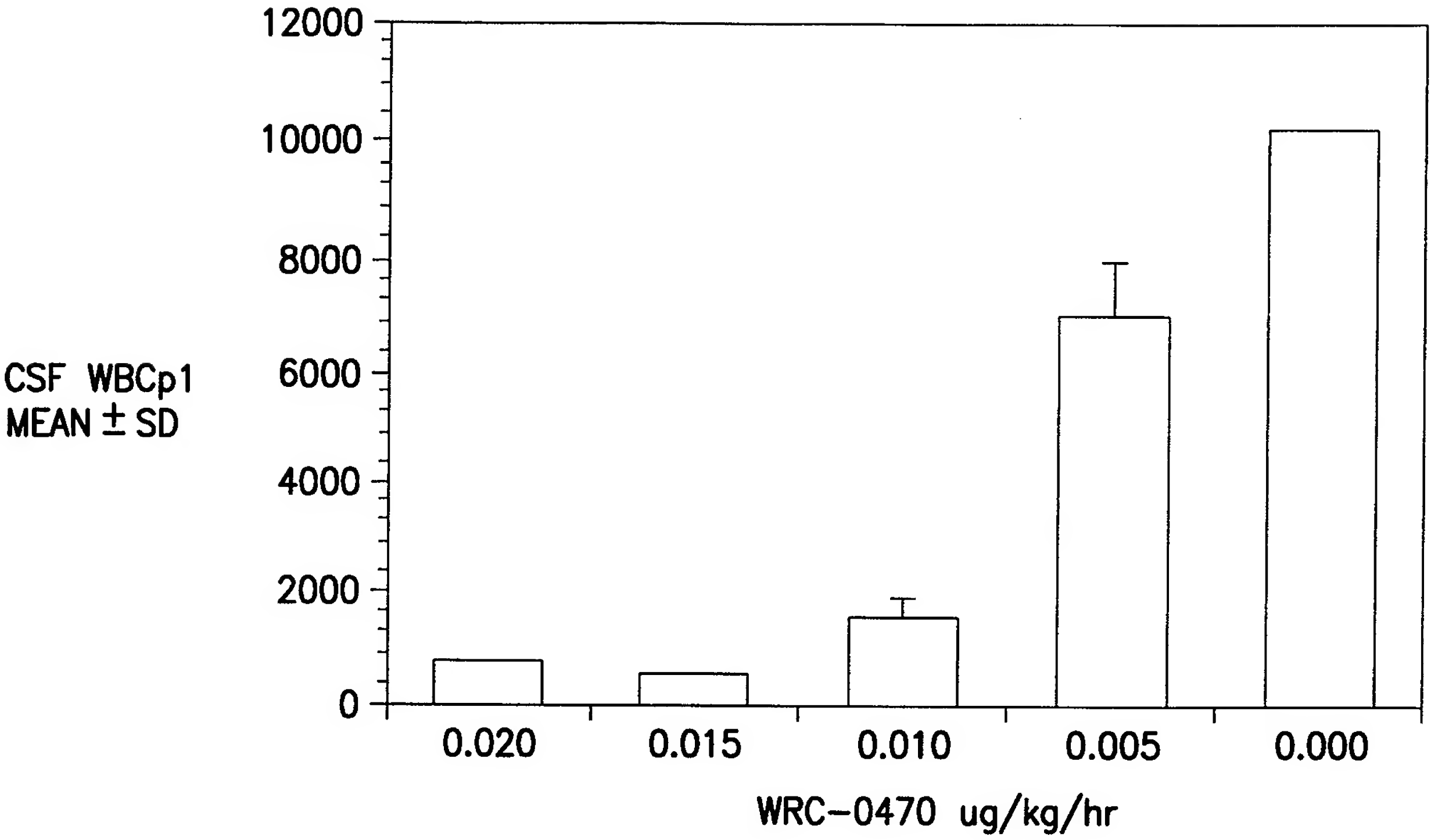


FIGURE 8

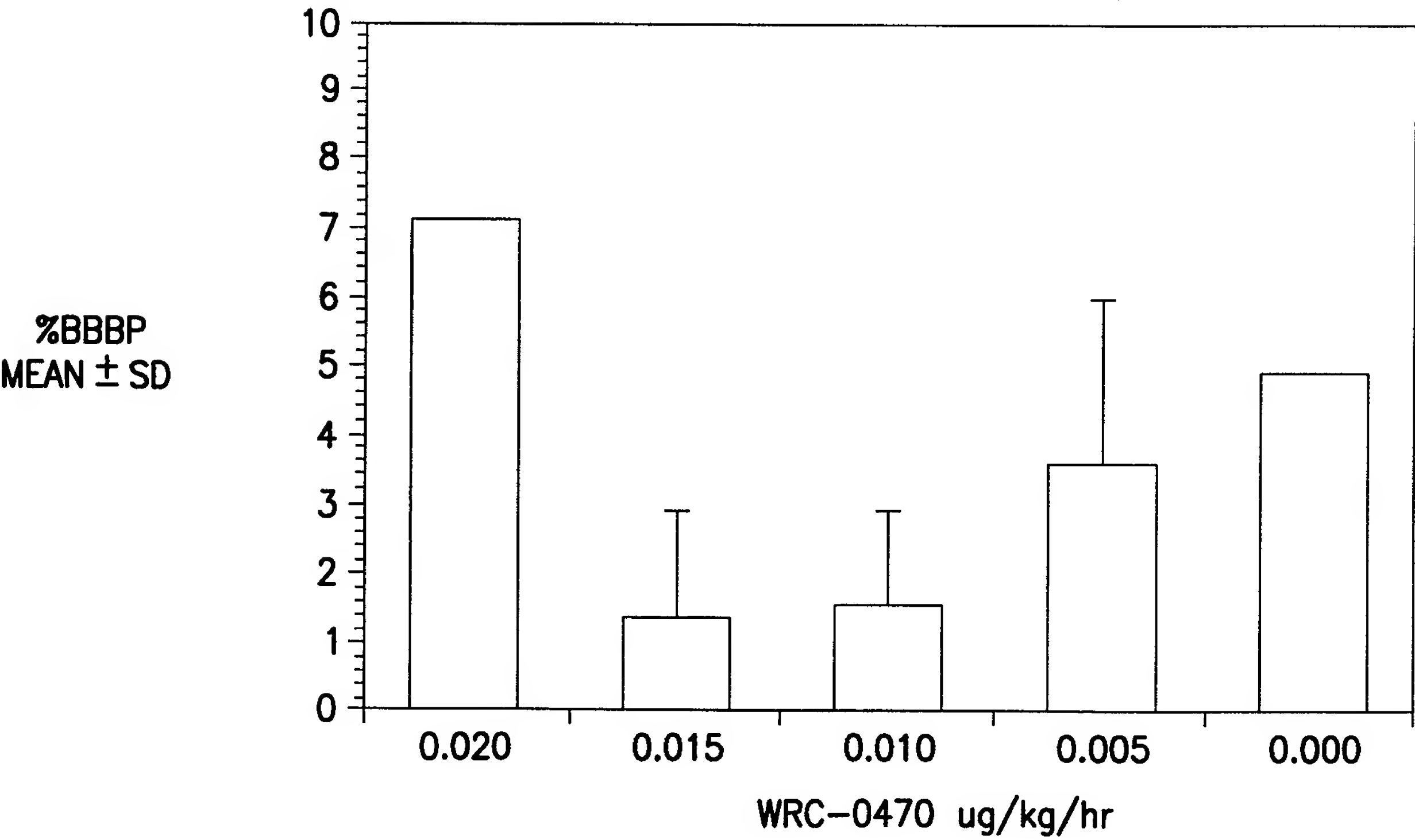


FIGURE 9



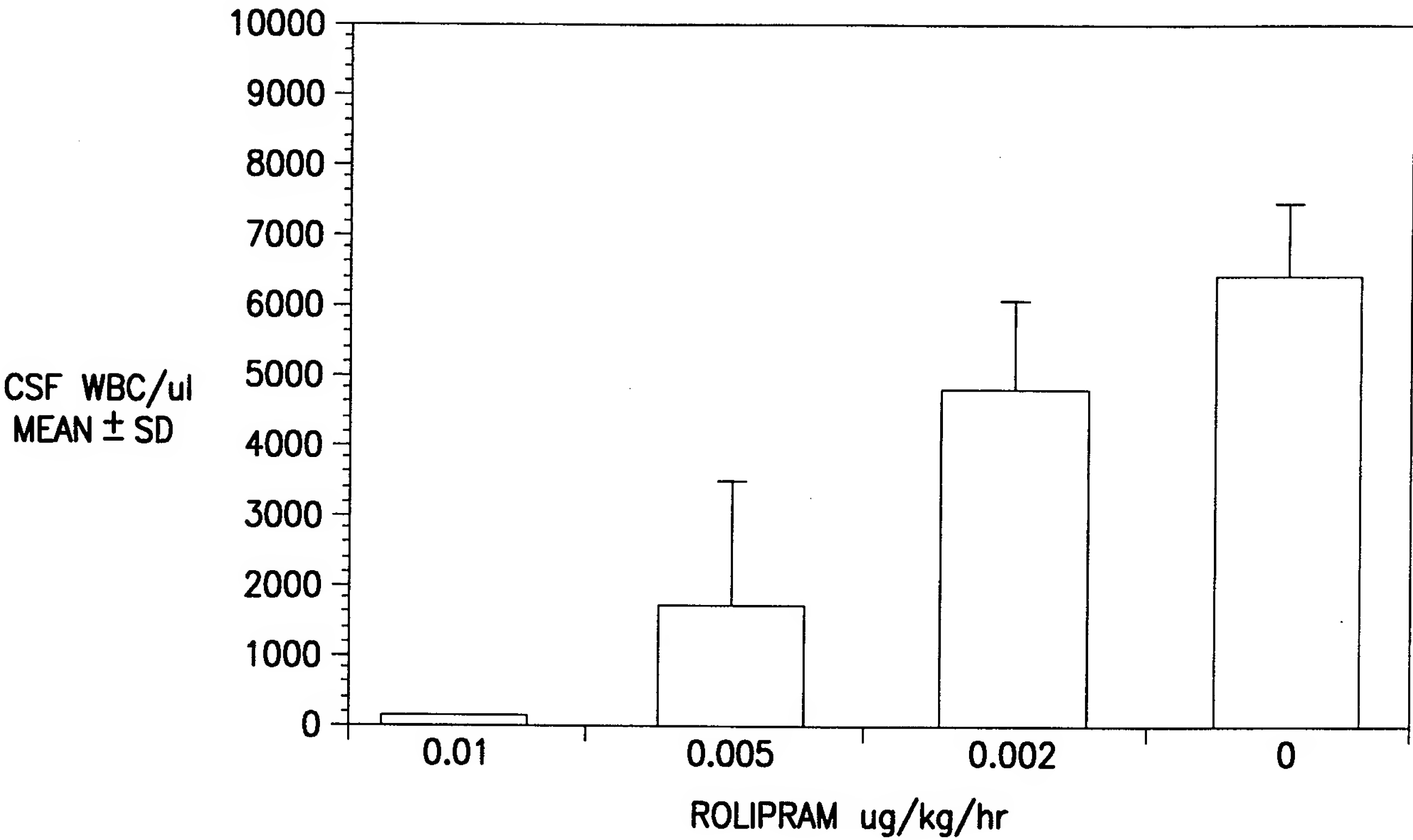


FIGURE 10

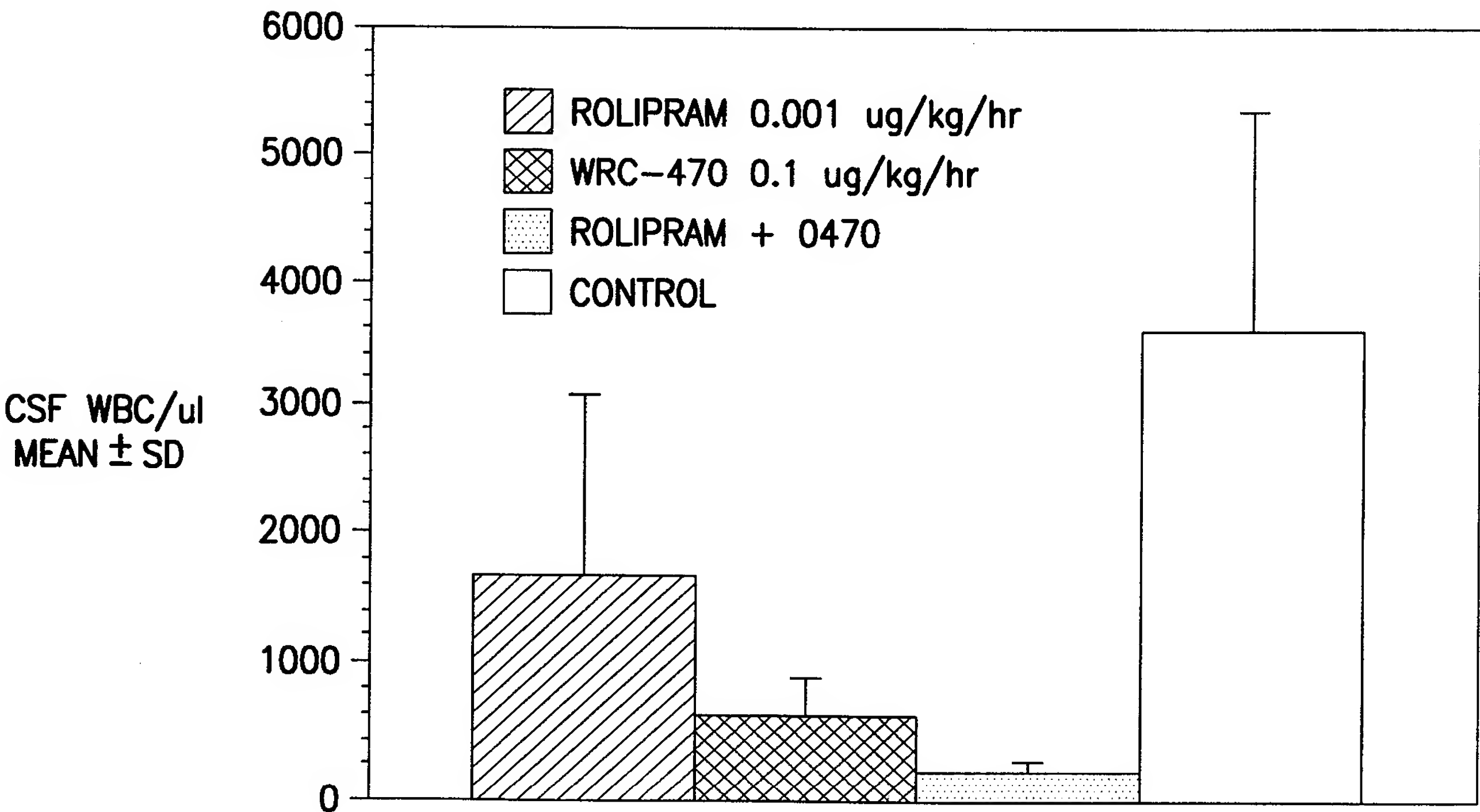


FIGURE 11

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/00366

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 A61K31/52 //(A61K31/52,31:40)

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|------------|---|-----------------------|
| X          | <p>BUSTER B(A) ET AL: "The effect of adenosine receptor agonists on neutrophil pleocytosis and blood-brain barrier pathophysiology in experimental bacterial meningitis."</p> <p>ABSTRACTS OF THE INTERSCIENCE CONFERENCE ON ANTIMICROBIAL AGENTS AND CHEMOTHERAPY, 1997, 37TH INTERSCIENCE CONFERENCE ON ANTIMICROBIAL AGENTS AND CHEMOTHERAPY, vol. 37, page 39 XP002104913</p> <p>see the whole document</p> <p style="text-align: center;">---<br/>-/--</p> | 1-8                   |

☒ Further documents are listed in the continuation of box C.

☐ Patent family members are listed in annex.

### \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

4 June 1999

Date of mailing of the international search report

17/06/1999

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Leherte, C

# INTERNATIONAL SEARCH REPORT

national Application No  
PCT/US 99/00366

| C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT |   |                       |
|--|---|-----------------------|
| Category   | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
| X  | <p>SULLIVAN GW ET AL: "The specific type IV phosphodiesterase inhibitor rolipram combined with adenosine reduces tumor necrosis factor-alpha-primed neutrophil oxidative activity."<br/>           INT J IMMUNOPHARMACOL;17(10):793-803 1995, XP002104914<br/>           see page 796, column 1, paragraph 3 - page 797, column 2, paragraph 2<br/>           see page 799, column 1, paragraph 3<br/>           see page 799, column 2, paragraph 6 - page 800, column 1, paragraph 1<br/>           ---</p> | 1-8                   |
| X  | <p>WALKER BA ET AL: "Adenosine A2a receptor activation delays apoptosis in human neutrophils."<br/>           J IMMUNOL, MAR 15 1997, 158 (6) P2926-31, XP002104915<br/>           UNITED STATES<br/>           see page 2929, column 1, paragraph 2 - page 2930, column 2<br/>           -----</p>   | 1,2                   |

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 99/ 00366

### Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1,9,10,11  
because they relate to subject matter not required to be searched by this Authority, namely:  
Remark: Although claims 1,9,10,11  
are directed to a method of treatment of the human/animal  
body, the search has been carried out and based on the alleged  
effects of the compound/composition.
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such  
an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all  
searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment  
of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report  
covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is  
restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

#### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.